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U. S. DEPARTMENT OF AGRICULTURE,
DIVISION OF ENTOMOLOGY.

THE HESSIAN FLY IN THE UNITED STATES.

PREPARED UNDER THE DIRECTION OF THE ENTOMOLOGIST,

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LETTER OF TRANSMITTAL.

U. S. DEPARTMENT OF AGRICULTURE,
DIVISION OF ENTOMOLOGY,
Washington, D. C., September 1, 1898.

SIR: In the letter of introduction to Bulletin No. 15, New Series, I mentioned the fact that the chinch bug was one of the most dangerous of the destructive insects of North America, and that the necessity for a complete and timely bulletin for distribution by this Department was emphasized by the almost daily demand for information. The same condition of affairs exists regarding the Hessian fly, and the accompanying manuscript, which has been prepared by Herbert Osborn, entomologist of the Agricultural Experiment Station at Ames, Iowa, and professor of entomology in the Iowa State Agricultural College, has been prepared by your direction and under the writer's supervision, to fill the want.

I recommend its publication as Bulletin No. 16, New Series.

Respectfully,

L. O. HOWARD,
Entomologist.

Hon. JAMES WILSON,
Secretary of Agriculture

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THE HESSIAN FLY IN THE UNITED STATES.

INTRODUCTION.

It is now seventeen years since any comprehensive treatise on the Hessian fly in America has been published. In the meantime so many important facts have been learned concerning the life history, food habits, and parasitic enemies of this important pest that such a treatise is urgently demanded. While the main object in such a review is the bringing together of these recent contributions with the important deductions with regard to treatment which follow, the fact that the elaborate essays by Drs. Fitch and Packard, so exhaustive for their time, are inaccessible to a great majority of farmers and even to many students, is a sufficient reason to present the details known concerning this insect.

In the following presentation the attempt has been to condense this information into as compact form as possible and to devote the greater part of the space to the questions having most practical importance and to facts giving the essential basis for remedial measures. In preparing the work the writer has been indebted to the exhaustive papers by Fitch (30)* and Packard (90) and, for recent contributions, particularly to the important papers by Forbes (34–39), Webster (137), Lindemann (60), and Marchal (71).

A list of the more important articles referring to this insect is given at the end of the paper, and will indicate the literature available, and avoid the necessity of too frequent references in the text. I am indebted to Dr. L. O. Howard for many notes and to Profs. S. A. Forbes and F. M. Webster for material.

IMPORTANCE AND EARLY HISTORY.

The Hessian fly probably ranks next to the chinch bug as a farm pest in the United States, and its ravages in other countries have long been known and appreciated. While its first scientific description was by Thomas Say in 1817, it had been for many years recognized as a pest in wheat and had received in this country the popular name of Hessian fly in the belief that it had been introduced by Hessian soldiers during the war of the Revolution. This belief, as we shall see later, seems to

* The numbers after authors' names correspond to numbers in a bibliographical list which is appended.

have been well founded, for while absolute proof of i
particular time and place is wanting, the evidence a
the insect was introduced from Europe at very nea
it evidently must have been brought in straw u
baling.

Dr. Fitch gives an exhaustive summary of the ea
spread of the insect from the point where first obs
cate a spread from Long Island into adjacent territo
mating 20 miles each year, and Packard has compi
showing the time of appearance of the pest in each
it is known to occur. The first scientific descript
1817 is rather exceptional, especially for the scien
that time, in that it contains a description of the la
adult forms, some details of life history, and rema
importance. This shows clearly how fully its injur
appreciated at the time, a recognition which was en
cific name, *destructor*.

Say's description and account must, however, ha
licity, for years later there appeared in no less p
than Silliman's American Journal of Science an ar
which purported to give a true account of the pest
many serious errors, the insect being referred to th
author evidently unaware of the more careful deseri
of Say. The article, however, contains some impo
history and emphasizes the importance of destroyi
in stack yards as a measure of control.

Dr. Fitch's elaborate monograph appeared in 18
by Dr. Packard in 1878 and 1880.

At about this time, between the years 1878 and 1
a somewhat lengthy discussion between Dr. H. A.
Prof. C. V. Riley (108–109) as to whether this pest
eign origin, but no economic question was involve
sary to discuss their papers here.

During the years 1887 to 1890 Professor Forbes,
of Illinois, devoted much of the effort of his offic
pest, and many interesting and valuable facts wer
ing the life history limits, especially the midsumm
insect. The important point was determined that
or even four broods in a year, dependent upon climati

Prof. F. M. Webster has contributed a number o
lished in experiment station bulletins of Ohio and I
Life.

In other countries the insect has received of late
attention. On its appearance in England it wa
Ormerod (84–85) and by Messrs. Enoch (25–26) and

In 1887 Prof. K. Lindemann (60), of Moscow, ma

of its distribution, injuries, and habits in Russia, determining particularly the variations of brood in different parts of the country, the effect of climate, and of limiting its food plants to wheat, rye, and barley.

An important recent contribution has been made by Dr. Paul Marchal (71), whose conclusions we shall have frequent occasion to use. He has determined that there may be as high as six broods per year; that the insect is greatly influenced by climatic conditions, has separated a distinct species affecting oats, and added greatly to our knowledge of the parasites.

In 1897 Prof. W. M. Schöyen,* the official entomologist of Norway, discussed its appearance in that country, pointing out that it was responsible for considerable damage, and showing that it had a wider distribution there than had been generally credited to it.

Still later, Dr. M. Paspelow (91), of Moscow, has added further details in determining the life history of the species and its habits in central Russia.

ORIGINAL HABITAT OF HESSIAN FLY.

Notwithstanding all the effort that has been devoted to determining the original home of the Hessian fly, we are still in the dark as to its exact original habitat and the exact time of its introduction into America.

Two difficulties which are well-nigh insurmountable must always obstruct such precise determinations. The earlier accounts, which might be interpreted as applying to this species, are all too vague to permit one to say absolutely that they do so apply, and no distinctive name, common or technical, is available to trace the species prior to 1778.

The name "Hessian fly" was first used for the species after its appearance in New York in 1778, and presumably on the ground that its introduction was attributed to the Hessian soldiers, although, as has been suggested by Hagen, such a name might have been applied simply as a result of the bitter feeling existing against these invaders, and which sought a vent in transferring their name to the detestable pests that were ravaging the wheat fields.

The fact that it is confined so strictly to wheat, rye, and barley, as food plants, should lead us to think that it has been associated with these as food plants from prehistoric times and to look for its source in the locality where these were indigenous. Inasmuch as this is a question impossible of absolute determination, although authorities generally refer their origin to western Asia, we have still a doubt; but, so far as America is concerned, we may reasonably conclude that as the hosts are introduced plants the Hessian fly is an introduced insect.

It seems unnecessary here to revive the controversy as to the introduction of this species, in view of the exhaustive papers by Professors Hagen and Riley and the evidence by the latter that all supposed

* Beretning om Skadeinsekter og Plantesygdomme, 1896, p. 8, Kristiania, 1897.

references to the Hessian fly before 1776 must in real to other species. Those interested will find full deta cited in the bibliography.

DISTRIBUTION.

At present the Hessian fly has a very wide distrib the wheat growing region of Europe and America. of its having existed probably from prehistoric time i southern Europe adjacent to the Mediterranean Sea, stated elsewhere, great probability that it has followe plant (wheat) from the supposed original habitat of th ern Asia. Its introduction into America has already and we need state here only those facts concernin throughout the United States that are of importan with the wheat industry. Its spread in this countr year 1776 was for a number of years at a pretty unif ress until it occupied the wheat growing district of th States. Following this, its distribution quite natur expansion of the wheat district associated with the settlement of the Mississippi Valley. Its eastward d to have been more gradual than the westward, a rece its extreme limit in Maine, at Bangor. Southward as the northern part of South Carolina, and in its limit in Texas it reaches nearly to the Gulf. We throughout a considerable part of Kansas, the eastern and northward, according to Webster, it has been Dakota, and records furnished by Dr. Howard place stone County, and Barrett, Grant County, Minn. (See r

On the Pacific coast it has been recorded for the te San Francisco by Koebele (55), and Professor Woo cusses its occurrence and variations in the wheat fields station at Berkeley. An article by Mr. A. Gains 41) bug and Hessian fly," in the Oregon Naturalist fo would indicate that it has appeared in Oregon, but at hand for a determination of the locality.

Professor Piper, of the Washington Agricultural C the Hessian fly is as yet unknown in Washington, alt fear of its introduction. Professor Aldrich, of the U says that it has not appeared in that State.

From this distribution it may be concluded tha has practically the same distribution as its food plan northern limit, where conditions seem to interfere w existence of the insect.

In Germany the Hessian fly has attracted frequent appears to be confined more to the southern provinc noticed, or at least not often destructive in the n (60) credits it to Silesia, Posen, Pomerania, Bavaria, a

In Austria-Hungary it is credited to Hungary, Carinthia, Istria, Moravia, Bohemia, "*Sachsen Coburg.*"

In Italy it has been located at Brindisi and Naples.

In Russia Lindemann states that it has a very wide distribution. Through his own researches and through numerous correspondents who furnished him material he located it in thirty-six different provinces, as follows: Bessarabia, Vladimir, Vologda, Volhynia, Kursk, Mohilev, Moscow, Nischni Novgorod, Samara, Saratov, Simbursk, Smolensk, Voronesh, territory of Don Cossacks, Eketerinoslav, Kazan, Kaluga, Kiev, Kostroma, territory of Kuban Cossacks, Novgorod, Orel, Penza, Podolia, Poltava, Pskov, Perm, Riazan, Stavropol, Tambov, Toula, Kharkov, Kherson, Tschernigov, Estland, Yaroslav.

In Norway Schoyen reports it as occurring at Hole, Ringerike, and points near Christiania.

In England the Hessian fly first appeared in 1886 in Herefordshire, Essex, and at other points.

In France the Hessian fly has been particularly destructive in Vendée, as recorded by Marchal (71), and it has also been credited to the province of Isère. Dana recorded its occurrence at Toulon.

So far there seems to be no record for Belgium, Holland, Denmark, or Sweden, although there would be good reason to suppose its possible occurrence in these countries, as also in Spain (recorded by Dana in the Island of Minorca) and in Portugal, where no observations seem to have been made. In quite recent years it has been introduced into New Zealand, as recorded in the following note from Insect Life (Vol. I, p. 32):

The Hessian fly halfway round the world—The Hessian fly, *Cecidomyia destructor*, has reached New Zealand. The March 1888 number of the New Zealand Farmer reports it from four different farms in the Rangitikei district, one of these being at Bellevue, near Marton, a town 33 miles southeast of Wanganui, in the State of Wellington.

MEANS OF DISTRIBUTION.

The powers of flight possessed by the Hessian fly are sufficient to provide for its ready dispersal over limited areas, and where there are continuous or slightly separated plantings of wheat, rye, or barley no other means of dispersal need be sought.

This natural spread was estimated by Fitch to be at the rate of about 20 miles per year in the vicinity of eastern New York, based on its extension from the center on Long Island, where it was first observed and from which it spread in all directions. This rate would seem to be as high as is admissible from purely natural means, as with plants at hand for deposition of eggs there is little tendency on the part of the insect to leave the field where it emerges, especially for the autumn brood. In the local transfer of straw, however, there is opportunity for some further dispersal which might supplement the flight of the insect in slight degree.

The only other means of distribution, and the only a possible basis for its transportation to distant regio riage of straw containing the puparia, or "flax see called. Under ordinary conditions it is evident tha be transported during the summer resting period o that puparia retaining their vitality must, in the brought into proper situations to permit the develop the emergence of adults. The winter "flax seeds," within the sheaths of growing plants and below th ground, could not furnish a means of dispersal, as at t means of distribution would be the shipment of growin transplanting in a new locality, a process certainly of as a probable source of dispersal. With ordinar the summer "flax seeds" there would appear to be scattering the insect in straw, especially since the these must be in the stubble remaining in the field It has been proved, however, that the puparia may re under certain conditions for long periods of time, ar which may be high enough to be taken from the fie would find most favorable conditions for the retardati opment so that they might be ready for the complet when the straw is scattered on moist ground in some bly far distant locality. The carriage, then, of pupar for packing and shipped from point to point would se means available for the wide dispersion of the insec method that its dispersal is generally credited. The the United States near New York City has as its most tion the straw used as bedding by the Hessian troops la and 1777, and while there is lacking positive evidenc existed at the point of their starting or even of embark of straw they might have used and scattered after l been in some infested locality, while the argument arrived at a time of year when the insect could not ported disappears when we recognize the possibiliti elsewhere discussed.

The recent introduction of the insect into New Ze to have been due to the scattering of straw used i merchandise, and while the exact time seems unkno that the introduction must have been in some such m important is the destruction of such packing materia where the insect is not present and where grain g consequence. Careful attention to this point may se at least for some time, the dispersal of the insect in th sections of Oregon, Idaho, Washington, and other where wheat culture is carried on in isolated district other wheat regions by extended ranges of mountain arid land.

OUTBREAKS IN SPRING-WHEAT REGIONS IN NORTHWESTERN STATES.

In 1896 there was a considerable outbreak of the Hessian fly in the spring-wheat region of northern Iowa, southern Minnesota, and probably a part of South Dakota. Professor Lugger (69) in Minnesota and the writer (89) in Iowa called attention to these occurrences in bulletins on the insect outbreaks of the year, and both noted the great abundance of parasites in the material received. The presence of the latter precluded the rearing of adults, but the characteristics of the attack, the distinctive features of the larvæ and puparia, and the fact that the typical parasites of the Hessian fly were reared leaves no question as to the species.

In the summer of 1897 the writer traveled over a considerable part of northwest Iowa and touched on southwestern Minnesota and eastern South Dakota with a view to examining the extent of injury, nature of the attacks, and so far as possible to study the conditions affecting the Hessian-fly outbreaks in this region. In nearly all the localities visited the injuries of the previous year had not been repeated, or the insect was present in such limited numbers as to cause very little damage and attract no attention from farmers.

In a number of the fields in the vicinity of Alta and Storm Lake, in Buena Vista County, there was a small percentage of injury, possibly 1 to 2 per cent, it being possible to find occasional stalks of wheat broken down in the manner characteristic of the Hessian fly and with larvæ or puparia in the usual position under the leaf sheath.

On farms where the year before there had been considerable injury and the crop had, following my suggestion, been early plowed under, there was no trace of Hessian fly even in large fields.

In Lyon County farmers stated that there had been injury in 1896, their description of the injury leaving scarcely a doubt as to the author, but no traces of Hessian fly were to be found during my stay in the county. I was informed that in the vicinity of Sioux Falls, S. Dak., there were several farms that had suffered the year previous, but here, too, I could find no evidences of the presence of the insect, nor could I hear of any injury for the season of 1897.

Examinations of fields in the vicinity of Cherokee, and Sioux City, Iowa, and Yankton, S. Dak., resulted in finding no infested fields, nor did I learn of any serious injury from Hessian fly theretofore.

A little later in the season (July 30), I received word from Mr. H. E. Crosby, Alta, Iowa, that he had examined several fields in that vicinity and found but few in which the insect was not present. Without stating definitely the extent of the damage, he leaves me to infer that the amount of injury was about the same as noted at the time I was there. I also received a communication from Mr. M. A. Marley, of River Sioux, in Harrison County, close to the Missouri River, containing reports of injuries in the wheat fields at that point and from his description there was evidently a greater amount of damage than in

the localities farther north. In general, for the territory lying north of 42½° north latitude west of the Mississippi River, the insect is practically unknown to the majority of the farmers and no account is taken of it in their calculations on the wheat crop.

The conclusion seems warranted that while the Hessian fly may survive in this region in small numbers, and occasionally so multiply as to attract attention in limited localities, that the conditions for its increase are too unfavorable for it to multiply greatly. These conditions would seem to be the general occurrence of a considerable period of dry weather in midsummer and autumn, and absence of food plants, thus forcing the insect to become single brooded. This greatly reduces its power of multiplication, exposes it to destruction by desiccation, or starvation, and the greater activity of parasites. If the insect ever becomes troublesome in this region it would seem a most simple matter to control it by simple adaptation of proper measures, especially the resort to burning the stubble and early plowing under, discussed in detail in the chapter on remedies.

From all that could be learned, and from the previous history of the insect in this region, it seems to me fair to conclude that the Hessian fly is not a menace to the wheat industry of this region, as was feared when its extension into this territory was first noted. The natural conditions prevailing in the region, with the ready multiplication of parasites, will serve to keep it in check during ordinary years. If farmers will only recognize the characteristic breaking down of wheat due to its presence, and in years when this is noted proceed to burn the stubble or plow it under and roll, they can prevent its multiplication and the possible damage that might follow in the succeeding year.

DESCRIPTION AND LIFE HISTORY.

The descriptions of the Hessian fly have been quite numerous, and some of them given with considerable accuracy of detail, so that there should be little difficulty in distinguishing the species from related forms. In many cases it is, however, deficient in characters which definitely separate it from the most closely related forms. It is clearly of no little importance to have a positive basis for the separation of the insect from related forms, particularly those which occur in closely related plants, and especially if they agree with it in the character of the puparia.

The adult insect (Plates I and II), like other members of the family Cecidomyidæ, to which it belongs, is a small, gnat-like, two-winged creature, about half as large as a common mosquito, which it resembles in form.

The female is about one-tenth of an inch long (2.5 mm.), of a dark color, the abdomen in freshly issued specimens appearing red, with black patches or bands of black, and with red bands at the articulations, depending upon the amount of distension.

The head is small, somewhat contracted dorsally, with a row of bristles on the posterior margin; eyes black, antennæ long, black, semipallid, usually of 17 joints, this number varying in different specimens from 16 to 18; joints rather short, cylindrical, and joined by a very short, small filament, each provided with an irregular whorl of fine hairs. The thorax has two rows of long backwardly curving bristles near the median line, and a patch on either side. The legs are long and delicate, with a dense covering of blackish scales dorsally, the basal joint of the tarsus very short. The wings appear smoky black from scaly covering, but the scales are very narrow, not broad, as those on the body and legs. The halteres are yellowish, with broad blackish scales covering the outer part, the basal part naked, except a narrow border.

The abdomen is long, ovate when contracted, but capable of great extension for the terminal segments. The ovipositor (fig. 1, *a*) is compressed, cylindric, very minutely hairy, with an oval lobe at the extremity, which is minutely striate and more densely hairy than the basal portion.

The male is smaller, more slender, and appears darker than the female. The antennæ are longer, the joints more distinct, 17 to 19 in number or 16 to 20 for extremes, and connected by a much longer filament, and the whorl of hairs is much more prominent, the hairs longer, and arranged in a more perfect verticil. The outer claspers (fig. 1, *b*) are very robust and apparently loosely connected to the abdomen. The basal part is heavy, with numerous strong tubercles and a few scattered bristles. The distal part is, when at rest, at nearly right angles with the basal part, narrower, faintly tuberculate, very minutely hairy, and with a strong claw like tooth at end. The inner claspers (fig. 1, *c*) are broad, oval, minutely hairy, the posterior margin with a row of fine hairs, and toward the apex three or four blunt teeth. Between the claspers is a strong chitinous process, and anterior and dorsal to them two pairs of finely haired, slender, finger-like processes directed dorsally; anterior to these, and forming the posterior border of the abdominal segment, is a prominent hairy rim, broken at the median line dorsally.

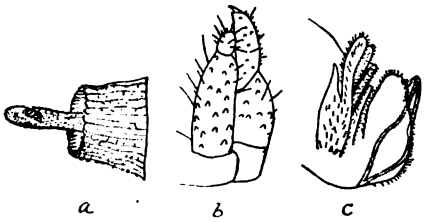

FIG. 1.—*Cecidomyia destructor*: *a*, ovipositor of female; *b*, outer claspers of male; *c*, inner claspers of male (original).

The egg is characterized as about one-half millimeter long, cylindric, roundingly pointed at the ends, glossy translucent, slightly reddish in color, and becoming deeper red with development.

The larva has usually been described without reference to distinct stages, but Marchal (71) has defined three forms, the first of which, just issued from the egg, is capable of locomotion and travels from the point

of hatching to the location under the sheath. Its size is slightly larger than the egg from which it hatches, and it presents thirteen segments, of which the first constitutes the head. It is distinguished from the second form principally by the presence of two triangular, fleshy, ear-like appendages, lightly incurved below on each side, and comparable to tentacles; the anterior buccal border is trilobed, and beneath is the mouth in the form of a small triangular opening. The last segment is lightly emarginate posteriorly, and each of the two lobes thus formed carries four setiform papillæ.

The second larval form, which is fixed to the stalk and is the one usually described by writers, is, when grown, 3 millimeters long by a little less than 1 millimeter wide, of a flattened, cylindrical form, and so transparent that the internal organs are easily seen. There are twelve segments beside the head, which is small and more or less retracted. The anterior end is narrowed and usually somewhat bent. The posterior end tapers, is bluntly rounded, and with two lobes on the posterior segment. The segments are but slightly indicated externally, but are plainly marked by the internal masses of adipose tissue arranged in series along each side, as well as the respiratory organs, the spiracles being plainly visible under the microscope as minute openings in rounded yellowish tubercles (Plate II B*c*). The mouth-parts are indistinct (Plate II B*b*), and the sternal spatule is, until the larva is ready to pass to the next form, either entirely wanting or inconspicuous. The digestive, nervous, tracheary, and adipose systems, which are very plainly visible in the larvæ, have been described in particular by Marchal, whose paper should be studied for details in this regard.

The third larval form—that inclosed within the puparium—is distinguished especially by the development of the sternal spatule or "breastbone." In other respects there is little difference anatomically from the preceding, but it is a quiescent not a feeding stage. The sternal spatule, which becomes conspicuous at this stage, is a horny structure projecting from between the first and second body segments, and is provided at its anterior extremity with two pointed spurs. The bifurcate form of this spatule is used by Marchal (71) to separate this species from *avenæ*, in which there is but one point. The use of this organ, which projects forward under the first segment and rests against its ventral surface, has been a subject of considerable discussion. The explanation which is best supported was proposed by Enock and is sustained by Marchal (71). This is that the spatule is used by the larva to reverse its position in the puparium so that, whereas the larva rests at first with its head downward and toward the roots of the plant, it rests, after turning, with its head upward and toward the upper part of the plant, a position which has obvious advantages when we consider the direction in which the pupa and imago must escape.

The pupa when first issued from the puparium is white, but acquires

a rosy tint. It presents a very delicate appearance, the pupal case being extremely thin. On the front is a prominent pointed chitinous rostrum of a brown color, the function of which is considered to be the cutting of the puparium to permit the exclusion of the pupa. Above the origin of the antennæ are two horns called by Marchal the cephalic horns and posterior to them two larger, curved, thoracic horns (Plate II C.) which contain, according to Marchal, trunks of the tracheary system.

DEVELOPMENT.

The deposition of the eggs has been described with great care by Herrick (50), as follows:

> The eggs are laid in the long creases or furrows of the upper surface of the leaves of the young wheat plant. While depositing her eggs, the insect stands with her head toward the point or extremity of the leaf, and at various distances between the point and where the leaf joins and surrounds the stalk. The number found on a single leaf varies from a single egg up to thirty or even more. The egg is about a fiftieth of an inch long; cylindrical, rounded at the ends, glossy and translucent, of a pale-red color, becoming in a few hours irregularly spotted with deeper red. Between its exclusion and its hatching, these red spots are continually changing in number, size, and position; and somtimes nearly all disappear. A little while before hatching, two lateral rows of opaque white spots, about ten in number, can be seen in each egg. In four days, more or less, according to the weather, the egg is hatched.

On the hatching of the larva and during its first or locomotory stage as defined by Marchal it moves down the leaf and along within the leaf sheaf until it reaches a position near the base of the culm. This in the case of fall wheat is close to the root and at or beneath the surface of the soil. In the case of spring wheat, when the eggs are usually placed on leaves above the first joint, they are just above the first or it may be the second joint; very rarely higher on the stalk.

Having reached this position the larva changes probably by a true moult to the second larval form, which is a sedentary feeding form during which there is no movement from the point where it has located, but has a fixed feeding period during which it secures all the material for its growth. At the end of this stage, which lasts on an average about twenty days, the larva contracts, and the outer larval skin forms a puparium, or sheath, within which the larva changes to the third larval form. In this retention of the larval skin as a protecting case the Hessian fly differs from most of the Cecidomyidæ and agrees with the more specialized flies of the house-fly group, and it would seem that this adaptation is one which has come with the peculiar restrictions of the species and the necessity it has encountered of adapting itself to varying climatic conditions.

While the third larval form is apparently a quiescent one and certainly one which is found capable of great modification in time, it really embraces some most important steps of development. While no nutriment is taken there is an important change in the tissue elements—the growth of histoblasts from which arise the rudiments of the

antennæ, eyes, legs, wings, and other organs which are not represented in the larva, but which appear in an advanced form when the change to pupa takes place. For these changes Marchal states his determination that moisture is absolutely necessary. It is during the early part of this stage that the reversal of position takes place that has been mentioned in connection with the description of the sternal spatule.

After the change to the pupa stage has occurred there is a variable period during which the insect remains within the puparium, and its issue doubtless depends on favorable temperature. The end of the puparium is forced off, and the pupa, by means of its pointed rostrum and movements of the body, extricates itself from the case and pushes its way out of the leaf sheath to freedom. Sometimes, according to Enock, it may cut its way directly through the leaf to the outside. The pupal sheath then quickly splits and the imago issues, leaving in the pupal moult a perfect but extremely delicate cast of the pupal form.

The lifetime of the adult is short, lasting only the few days necessary to the processes of mating and deposition of eggs. If delayed in these, it may probably survive several days; if they are accomplished promptly, its life may be measured by hours rather than days. Copulation is said to take place usually very shortly after emergence, and generally toward the middle of the day, lasting but a few seconds, and one male is capable of fertilizing several females. Fertilization appears to be necessary to the development of the eggs, as records show that unfertilized eggs fail to develop. It may be assumed, therefore, that parthenogenesis is impossible as a normal feature, and that in case isolated females issue in new territory there would be scarcely a possibility of their establishing a colony.

We come now to the consideration of the number of annual generations and the questions of acceleration and retardation, which seem to me so closely related as to be best discussed in one connection. This subject presents especial importance from the practical side, as the most important means of control available to the cultivator are dependent upon it.

ANNUAL GENERATIONS.

An insect that can adapt itself to all the climatic conditions and crop variations between North Dakota and Texas must necessarily be able to vary its life history in no small degree. The Hessian fly presents variations not only in the number of broods, from one to possibly five or six, depending upon latitude, but, by acceleration or retardation, under conditions peculiar to each year, it may appear earlier or later and in a greater or less number of broods in the same locality. This variation naturally enhances the difficulty of stating life history details with precision and making recommendations as to particular dates on which to adopt measures of control.

The earlier writers detailed two broods for each year, the adults

appearing in autumn, laying eggs on fall wheat, the larvæ feeding and reaching puparia prior to winter, pupating and issuing as adults in spring to produce the spring brood of larvæ, these maturing before harvest and the puparia resting during the summer to produce adults in autumn.

This cycle is doubtless the most universal and will apply particularly to a large section of winter wheat cultivation under normal seasonal conditions. It is especially the normal round in the eastern United States, where all the earlier studies were made, and there is no occasion to criticise the careful work of Chapman, Tighlman, Herrick, and Fitch. Nevertheless, recent studies have shown wide departures from this normal cycle, and these variations are of the utmost importance in determining the successful application of remedial measures. It will be in place, therefore, to review with considerable care the results of investigations upon this subject.

As early as 1877 Professor Riley called attention to the effect of the weather upon the abundance or rarity of the Hessian fly, and in 1881 noted (in the American Naturalist, vol. 15, p. 916) the effect of drought upon the insect, as follows:

> It has long been known that the Hessian fly flourishes best when the chinch bug flourishes least; in other words, that wet weather favors it. Moisture seems essential to the well-being of the larva. The prejudicial effect of drought has not been hitherto observed, that we are aware of, but was very noticeable the past year in parts of Ohio, where the puparia literally dried up. Our attention was first called to the general death of the insect in the "flaxseed" state by Mr. E. W. Claypole, of Yellow Springs, Ohio, and our observations subsequently confirmed his experience. The intense heat had not only desiccated the Cecidomyia, but what is still more remarkable, in most cases the parasites also. We should like to hear from Professor Cook, of Michigan, and others, whether a like result followed the severe heat and drought in other parts of the West. The presumption is that the mortality was general and that farmers may expect immunity from injury for some years to come.

Lindemann (60), in 1887, in publishing his extended account of the Hessian fly discussed in considerable detail the number of generations and time of appearance in different parts of Russia. For central Russia, in the latitude of Moscow, he concludes that there are three different broods having well-marked periods, the flies of the spring brood issuing from the fore part of May to the fore part of June; those of the summer generation from June 19 to the 1st of August, and those of the autumn generation from the last of August. Farther south he notes the appearance of the spring generation by April 20, the summer generation June 7, and the autumn generation July 21.

In 1890* Professor Forbes published the following succinct statement regarding the observations in Illinois:

> The history of the Hessian fly during the past two years exhibits anew the effect of drought upon the multiplication of that species. Many of the wheat fields of southern Illinois, in regions which had been free from the fly the preceding year, showed it

* Sixteenth Rept. State Entomologist of Illinois, pp. x–xi.

in such numbers at harvest time in 1887 as to make it seem probable that the following crop would suffer heavily, but a severe midsummer drought following prevented almost entirely the growth of the volunteer grain, and very probably also dried up the larvæ and pupæ of the fly in the field. As a consequence these neighborhoods in 1888 were almost absolutely free from evidence of attack, although in adjacent counties, where the drought was less severe, the fly was noticeably abundant in the fall of 1887 and in the following spring.

Experimental sowings in 1887 and 1888, made to trace the summer history of this insect, failed because of the drought—in the former year completely, in the latter partially—only the latest planting growing. One plot, sown at Albion, Edwards County, July 28, started slowly, and was heavily attacked by chinch bugs and grasshoppers. There no Hessian flies were detected August 24, but by September 13 larvæ of almost all ages occurred in great abundance, and by the 18th a few had formed fresh puparia. Transferred to the office at Champaign and kept in the open air, the first imago (a female) emerged October 9, a male October 10; October 16 two more females appeared and another male; October 27, one female and three males. On the final search in the cage, made November 12, a female was found dead with eggs near her. Compared with our previous record, as presented in the Fifteenth Report and in my Office Bulletin No. 3, these data merely bring the appearance of this autumnal brood about ten days earlier. An attempt to secure fertilized eggs and rear larvæ from the imagos hatched as above failed, probably because the small number of specimens reared and their scattered appearance prevented copulation.

In 1891 Prof. F. M. Webster (137) published data concerning the unusual appearances of adults, and sums up the results as follows:

From this it will be observed that the adult flies may emerge and oviposit under what we suppose to be very adverse circumstances. To what extent the eggs and young larvæ are able to withstand such weather I have no facilities at present for demonstrating. The major portion of the fall brood of flies, however, emerges during a more favorable period, and for meteorological aid against these we can only look to the dry, hot weather of July and August, though to the south a portion of September might be included. But the straggling individuals which as I have proved may originate from stubble, volunteer, or even early sown grain, and which I myself can find no satisfactory reason for not considering either the retarded or accelerated individuals of either one or the other or both broods, have it in their power to produce a considerable progeny, which, though of themselves not a serious menace to the crop, yet added to those of the remaining forthcoming brood, greatly increase the probabilities of serious damage. For these a long mild autumn, extending into December, would appear to be exceedingly favorable, as it would enable their progeny to enter winter in a comparatively hardy state, and probably produce late appearing larvæ the following year simultaneously with or but little in advance of the earlier appearing adults of spring. In other words, the one winter as advanced puparia or unemerged adults, the other as advanced larvæ or newly formed puparia. It appears that while the autumn usually has little effect upon the major portion of the fall brood, a mild October and November may emphasize the destructiveness of the pest. So far as observed by me, a damp spring, even though a cold one, is also favorable to the development of the insect, while dry, hot summers are unfavorable, and cause serious mortality to the earlier stages of the fall brood of adults.*

In France Dr. Paul Marchal (71) has made an extended study of the development of the Hessian fly, and the results of his investigations are of more than usual interest and importance. The studies were made during the years 1894 and 1895, but have only recently been

* Bul. Ohio Agric. Exp. Sta., N. Ser., v. iv, No. 7, p. 153.

published. His material was secured from Vendée and his experiments made on the grounds of the Institut Agronomique in Paris. His method consisted in inclosing a series of plats so as to avoid any possible infection from without and then transferring the progeny of each generation to fresh unaffected plats, thus keeping up a continuous series of breedings, the ordinary breaks being provided against by the fresh sowings of grain, so that proper food plants were available for each period. Starting with imagos issuing April 5 from puparia collected March 12, he obtained a second generation of imagos May 30, and introducing these in the second case, found flies of the third generation flying July 1. In like manner the progeny of this generation developed adults by August 5; the succeeding generation, the fifth, appeared September 4, and on October 18 the first individuals of the sixth generation, this last depositing eggs which produced larvæ that changed to puparia and entered upon the winter hibernation. At the same time observations were made upon the succession of broods appearing in the inclosed plats supporting the first, second, and third introductions, which served as a check upon the isolated rearings. The separate rearings, however, give the most positive evidence as to the possible number of broods, and his conclusions from these experiments are that under favorable conditions for development the Hessian fly may present as many as six or more generations. These generations are distributed as follows: The first occurring from April 5 to April 25; second, from May 30 to June 15; third, from July 3 to July 20; fourth, from August 5 to September 1; fifth, from September 10 to October 15; sixth, from October 18 to the end of the season. The most of these generations are partial, and the more incomplete are the third, the fourth, and the sixth.

The conditions necessary to such a continuous series of broods are of course not present in nature, and Marchal calls particular attention to the necessity of proper plants and humidity as conditions which are far from being associated in nature. This results in a great irregularity for the different individuals. In the absence of proper food plants such females as might issue would be unable to perpetuate the species. Others deposit upon leaves which may be harvested and the larvæ perish. Certain puparia directly in contact with the moist earth pursue their development rapidly, others inclosed in dry stems have their evolution retarded. The different generations, therefore, intermix in a very irregular manner, and among individuals which fly at the end of the year there might well be found those belonging to the third, the fourth, or even of a still higher number of generations. The extreme fecundity of the insects and this great irregularity of development permit the insect to perpetuate itself in spite of a want of natural food plants during the period of summer heat and to adapt itself to the conditions of the season.

He further points out that in a year presenting for example a moist month of July the third generation would almost entirely issue and

then it could deposit only on the shoots which develop at the base of the wheat following the attacks of the preceding generation. A great number of the individuals would perish, and the same remark would apply for the fourth generation if the month of July and the beginning of August are very rainy. In a country presenting the agricultural conditions of Vendée a great humidity during the month of July and the commencement of August would be unfavorable to the development of the Cecidomyia in causing a quantity of individuals to issue which would perish for want of suitable food plants. Dryness during the same period would, on the contrary, be favorable in permitting the estivation of its progeny.

Quite recently Dr. W. Paspelow, assistant in the zoological cabinet of the Agricultural Institute at Moscow, has published a communication presenting a number of facts concerning the development of the Hessian fly, a translation of which, by Mr. C. W. Mally, has been kindly furnished me. The following extract contains the points that are of interest in this connection:

The spring generation of the Hessian fly appeared this year in the second half of April (old style) and deposited its eggs principally on the young wheat sowings (or wheat plants) and in much smaller numbers on the rye sowings (or rye plants). Such a selection was only found in connection with the spring generation.

In the autumn, on the contrary, the rye as well as the wheat fields were attacked by the Hessian fly, whereby the early (July) as also the late (August) sowings suffered in equal proportions.

The larvæ of the spring generation damaged in the wheat fields 50 per cent, and in the rye fields 20 per cent of the stems.

Toward the end of May the greater portion of the larvæ transformed to the puparium stage. In the beginning of July the first true pupæ were found, and at the same time adult flies emerged from pupæ kept in a glass. In the first half of June a number of the puparia transformed to true pupæ; but the principal portion of the Hessian fly (70 to 80 per cent) remained in the puparium stage. Toward the end of the same month there were no more true pupæ to be found, and during the whole of July and the first half of August there were in the field exclusively puparia to be found. As an indirect proof of this—that the Hessian fly was retarded in its development—is given the fact that the wheat and rye sown during June for the purpose of attracting the Hessian fly remained entirely free, although at the same time they suffered greatly from *Oscinis frit* Fall., and the "ground flea" (*Chætocnema aridella* Gyll.). From this we can deduce that the emerging of the summer generation, which had begun in June, stopped very quickly, so that the same first appeared in the autumn—end of August and beginning of September. Such a retardation in the course of development of the Hessian fly was due to the high temperature and the great drought of the past summer, whereof one could easily be convinced by placing the puparia in a moist space—in glasses with damp sand which were placed in moist and shady places in the park. In all such cases perfect flies developed in the course of two weeks from puparia brought from the field. Puparia left in the field, remained on the contrary, in the puparium stage an unusually long time, until in the second half of August, under the influence of rain, they transformed first into true pupæ and after that finally into adult flies. So there were in the past summer only two generations of the Hessian fly observed—the spring and the autumn generation.*

*It is not without interest to remark that, in the room in which the summer puparia were kept dry, they remained without change during the course of the whole autumn and winter.

The weather conditions of this year increased the difficulty of fighting the Hessian fly in high altitudes. The wheat fields, namely, which were sown in June for the purpose of attracting the Hessian fly, could not fulfill their mission, because the fly at this time had not yet emerged.

The recommendation made by several entomologists to delay the sowing until August could not protect the crop from the Hessian fly, because it emerged just at this time. The plowing under of the stubble after harvest proved itself the only method applicable in this season to accomplish the destruction of the puparia contained therein. Although in this wise the weather conditions of the past summer greatly increased the difficulty of combating the Hessian fly, they proved themselves, on the other hand, to be unfavorable for the life of the fly itself. Simultaneously, with the retardation which the puparia of the Hessian fly experienced under the influence of the dry and hot weather, there took place the rapid increase of its enemies—parasites from the subfamily Pteromalinæ, which under these unfavorable conditions overrun the Hessian fly in great numbers and destroyed 50 to 70 per cent of its puparia.

A letter from Mr. John C. Andras, of Manchester, Ill., to Dr. Howard bears so directly on this point that it is reproduced here, and, although it will be seen that it is in large part covered by observations already cited, its corroborative value will justify its introduction:

On examining some fields of spring wheat that were destroyed by what farmers thought to be chinch bugs, I found the Hessian fly was the real cause. The spring wheat was sown on killed-out winter wheat early sown in September, 1896. The spring wheat sown early in March, 1897; the killing out of the fall was complete, hardly a single plant left.

By the surroundings it seems the Hessian fly in the puparium stage was not destroyed, but the warm days of the latter part of April brought them to the mature form, and egg laying began, the larva going below the ground one-half to 1 inch deep. The puparium cases are abundant on, or in, the extreme lower clasping base of the almost killed plant (spring wheat), and the mature fly is laying eggs on the blades at the present time. This cycle seems to point to a more rapid maturity than I supposed this insect went through. From the middle of March to the 28th of May has completed the period from egg to maturity, and with the present egg-laying would give the second brood by harvest. The usual damages here have been from the eggs laid in early fall (September), the perfect insect in May laying eggs about 2 inches from the ground, which matured in June, this last being the injurious brood. But this spring-wheat brood has completed one brood at present (May 29) and would complete the second brood by harvest (middle of July is our spring-wheat harvest), which is making them double brooded by end of our harvest season.

I note in the American Entomologist, page 118, volume 3 (Sec. Ser., vol. 1) that "spring wheat can rear but one brood," but where the puparium is left in the ground from the winter wheat being killed out by freezing, they will raise two broods by spring-wheat harvest time in this locality.

My own observations in this direction have been devoted more particularly to the spring-wheat regions of the Northwest, as here the occurrence of the insect presents some interesting problems.

The material I obtained in 1896 produced only parasites, and these in considerable numbers, so that only negative evidence was secured as to the amount of retardation resulting from conditions prevailing in this region.

Prof. O. Lugger reports almost identical results in Minnesota. After mentioning its occurrence in the central western part of that State, from Browns Valley to the Mississippi River at St. Cloud, and esti-

mating the damage as high as 25 per cent in some places, and at from 5 to 10 per cent of the entire crop, he says:

In Southern States this insect is double brooded and hibernates in the "flaxseed" stage in winter wheat, volunteer wheat, and in other plants, including, possibly, some of the larger grasses. But this is their habit only in the South. Here the insect must lead a different sort of a life, for instead of being double brooded it is single brooded. This could be expected from the conditions prevailing in the greater part of the State, but we have had no proofs thus far. Of all the infested stalks gathered as soon as the injury became visible, not a single Hessian fly has issued, and numerous puparia (the "flaxseed" stage) are still unchanged in the breeding cages. This assuredly seems to indicate that the flies do not issue during the autumn, as they do farther South, but remain in the culm until spring. Another proof, though not a safe one to depend upon, is the fact that no larvæ or puparia could be found in the volunteer plants of wheat growing near fields that had been badly infested. The many puparia kept in properly constructed breeding cages gave forth, however, very large numbers of parasites. Three different species were raised, and in such numbers that in some cases nearly all the Hessian flies had been destroyed in the puparia.

For all of the material collected in 1897 the failure to produce adults was fully as manifest, and it seems to me that in many cases the retardation amounted simply to the death of the insect. Even when not producing parasites the puparia have failed to produce adults, and it would seem that the process of desiccation had gone to the point of destruction before conditions permitted the development of the insect. In many cases the puparia were shriveled and gave evidence of incomplete development, and I suspect that in many cases the straw had ripened and cut off their nutriment so early as to prevent maturity. This might easily occur if the adults emerged and deposited eggs a little late in spring. The occurrence of a cold, late spring would here favor the retardation of emergence of the adults and allow such maturity of the wheat as to largely prevent development of larvæ, and as such conditions are of frequent recurrence in this region there would seem to be in this a natural check on the species that may be sufficient in general to limit the insect to harmless numbers.

I have, on the other hand, seen the early maturity of Hessian flies in breeding cages; as infested wheat sent me by Professor Webster during the past winter produced flies emerging from March 4 to 7, and specimens of puparia kept in an office room before being sent to me emerged still earlier.

With the amount of evidence that has now accumulated there seems no longer any possibility of questioning the acceleration and retardation of the insect for conditions of latitude and of climatic variation within the same locality. Further, it appears to me that we have sufficient evidence to conclude that the conditions affecting this acceleration or retardation are temperature and moisture, and that with a knowledge of these conditions it should become possible for the intelligent cultivator to foresee the occurrence or absence of the pest to such an extent as to adapt his agriculture to the avoidance of their injury. The methods for such adaptation naturally fall under the discussion of remedies.

FOOD PLANTS.

The question of the food plants of the Hessian fly presents a particularly important one, for the possibility of its survival in a district where its normal food plants are not grown during one or two years, or of its living for one or two broods on grasses, so as to adapt itself better to crop conditions of cereals, all depend on whether it can exist on other than its principal known host plants.

From early times the Hessian fly has been recognized as a pest of wheat, rye, and barley, and most of the early literature considered it simply as a pest of these crops. Some years since, however, the point was made that it could live on various grass plants, and some observations by careful observers tended to support such a view.

The following extracts from reports on this point will show the nature of the testimony submitted:

The Hessian fly attacking grasses in California.—According to Lindemann, the Hessian fly has been found upon *Phleum pratense* and *Agropyrum repens* in Russia, but up to the present year it had not been recorded as occurring in this country upon any wild grasses.

We are in position now, however, to add four grasses to the list of its food plants in the United States. In 1887 Mr. Koebele sent us from Alameda, Cal., specimens of *Elymus americanus* and of a species of Agrostis which bore puparia supposed to be those of this insect. The adults were not reared, however, and the question remained unsettled. On page 71 of the current volume we published, under the head of "California notes," a letter from Mr. Koebele, in which he mentioned finding Hessian fly puparia in a grass in the Santa Cruz Mountains. This fact was called in question by Mr. James Fletcher, and we wrote Mr. Koebele for specimens and received from him *Bromus ciliatus* and a species of Agropyrum, both carrying puparia. These were very much like the normal puparia of the Hessian fly, but were smoother and more plump, showing little trace of the longitudinal ridges. Flies were obtained from these, and others also obtained from the grasses were sent on by Mr. Koebele; and, after comparing these very carefully with specimens from wheat from different parts of the country, we find they are not to be separated, although from the specimens first received a variation in the number of the antennal joints raised some doubts. We find, however, after the examination of nearly 100 specimens of individuals reared from wheat from various sections that the joints of the antennae in the male range from 16 to 20 and in the female from 16 to 19.*

On the other hand, we have, aside from all the early history of the pest, a number of positive records which strongly confirm the view that the insect never occurs normally or survives on other plants than wheat, barley, and rye, which are in closely related genera.

In 1890 Professor Forbes undertook to prove experimentally whether the Hessian fly could develop on other plants than its usual hosts, and to this end introduced flies into cages with timothy, redtop (*Agrostis vulgaris*), blue grass (*Poa pratensis*), orchard grass (*Dactylis glomerata*), and foxtail (*Setaria*), in all cases without result, though in some cases active adults had every opportunity to deposit eggs. While Professor Forbes gives this result only negative value, it is certain that it gives no support to the idea of a variety of food plants, and, taken with the

* Insect Life, Vol. III, p. 306.

other evidence now available, would seem to favor the conclusion that wheat, rye, and barley are the normal and only food plants of the species.

With regard to the identity of the specimens obtained from Elymus in California, Dr. Howard considered there was some doubt, and submitted the material to Mr. Theo. Pergande for critical comparison, the result of which is presented in the following record:

4855. *Cecidomyid on Elymus americanus, not the Hessian fly.*—Examined and compared larvæ and imagos of the Cecidomyid from Koebele (4855) with those of *Cecidomyia destructor* with the following results:

The differences in the imagos of both are very small, though I find in the male of the Hessian fly that the inner pair of claspers are provided, near or close to the apex of the posterior edge, with four or five stout and blunt teeth, and that the large basal piece of the external claspers bears, near the lower external edge, a number of stout, conical, black tubercles.

In 4855 the teeth of the inner claspers are wanting, while the whole posterior edge is strongly serrate. The tubercles of the external claspers are rather small, colorless, and difficult to be seen.

The hairs of the genital organs and the tubercles from which they arise are also more prominent in the Hessian fly than in 4855.

Of the larvæ of the Hessian fly we have only such as were taken from the puparium. Whether or not these materially differ from those before pupation I am unable to say, though the figure in Packard's Bulletin No. 4 indicates that there are two tubercles at the end of the body, whereas in 4855 this segment bears four large and acutely pointed processes, entirely unlike those of the Hessian fly. These differences in adult and larvæ seem to be of enough importance to consider 4855 to be a different species.*

Professor Lindemann, in 1887, believed he had sufficient ground to declare that the Hessian fly develops only in wheat, rye, or barley, never in other grasses, this conclusion being based on extended and careful observations in fields where a variety of grasses occurred. Later (in 1888) he seems to have felt it necessary to revise this opinion, and records having larvæ sent to him that were found upon timothy (*Phleum pratense*) and *Triticum repens*, and also on account of the record by Mr. C. H. Whitehead of the occurrence of the puparium on *Holcus lanatus*.

Marchal, in reviewing this question, suggests that Lindemann has given unnecessary weight to these observations, and that even if comparisons with larvæ or adults showed close similarity, it would still be necessary to prove their identity from biologic criteria. His own results convinced him of the close limitation of *C. destructor* to wheat, rye, and barley, and he separates the species *avenæ* finally on careful experimentation, that proved the inability of *destructor* to survive on oats or of *avenæ* to live on wheat.

There seems strong reason, in view of the evidence produced by Marchal and the differences indicated by Pergande, to adopt as final the position taken by Marchal. While precise experimental evidence in

* Department record made by Theo. Pergande.

each case may be desirable, we have the general fact that throughout an immense territory in the United States where wheat is grown in close proximity to oats, timothy, and other grasses, we have never had a record of the Hessian fly's attack upon these crops.

In any deductions, therefore, relating to the control of the Hessian fly, it may be considered for all practical purposes that the insect lives only on wheat, rye, or barley, and will not perpetuate itself on other plants.

EFFECT UPON THE PLANTS.

The attacks of the Hessian fly upon the plants produce very characteristic effects, generally so distinctive that the appearance of a field will at once indicate to a practiced eye the presence of the pest. The effects differ with the season, perhaps, more properly, with the stage of growth of the wheat plant at the time of attack.

In autumn the eggs are laid upon the early appearing leaves and the passage of the larvæ down the sheath carries them down to or below the surface of the ground, often very near to the root itself. Here their presence causes more or less swelling of the base of leaf and culm, scarcely enough to be counted a gall formation, but the immediate effect seems to be a stimulus at the point of attack. Indeed, as Webster has pointed out, the affected plants present a darker green color, which has been recognized by farmers as indicative of Hessian fly attack, this color to be followed later by a brownish and then a yellowish color for the infested tillers. If the plant is attacked early and fails to tiller, the result is death of the whole plant; if tillers have already formed, the larvæ may enter but one or part of them, and the others may develop into healthy stalks and furnish the basis for a crop.

The attack in spring being made usually after the stalks are well formed, the eggs are placed on the lower leaves, and the larvæ, as a rule, will be found just above the first joint. Their presence here so weakens the stalk that it bends over, the upper part of the stalk falling to a horizontal position and at right angles to the base. The appearance of these fallen stalks is particularly characteristic, and an examination will bring to view the larvæ or puparia just below the bend and above the lower joint. Rarely the larvæ may occur above the second or third joint, and it is stated that sometimes they pass below the ground, as with the autumn brood, and in such case the stalk falls by breaking at the surface of the ground. These facts have a value not only as a means of distinguishing the Hessian fly from other wheat pests, but it can easily be seen that the position of the larvæ must be a determining factor in the adoption of certain measures of control.

NATURAL ENEMIES OF THE HESSIAN FLY.

The importance of the parasites of the Hessian fly is probably hard to overestimate, since to this factor we have doubtless to refer the usual scarcity of the insect. This may be inferred, in part, from

the fact that Say, in his original description of the *Cecidomyia*, presented a description of one of the most abundant of the parasites which was already at that time recognized as an efficient agent in the destruction of the pest.

It is also shown by the estimate commonly made by the writers who have dealt with the subject that fully nine tenths of the Hessian flies are destroyed by parasites, a circumstance which accounts for the fact that the Hessian fly is seldom abundant or excessively destructive for more than one year at a time in any particular locality. In the specimens which were received from different points in Iowa in 1896 I was unable, because of the parasites, to secure a single perfect fly, and I am informed by Dr. Lugger, the State entomologist of Minnesota, that his experience for 1897 was the same as reported in his annual report for 1896.

This being the case, there is abundant reason for a careful consideration of the various species known to attack it, and the presentation of descriptions whereby they may be recognized should be one of the most serviceable parts of a discussion of the insect.

An interesting comparison of the parasites of the insect in Europe and America has been made, whereby it has been brought out that there are similar parasites in the two regions, and, furthermore, that in some cases where the species do not appear to be identical the same genera are represented, and that a list of species presenting counterparts may be arranged for the different regions where the insect occurs. A comparative list adapted from Marchal will be useful to show this point.

PRIMARY PARASITES.

For America the following species have been recorded:

CHALCIDIDÆ.
Merisus destructor Say.
Bæotomus subapterus Riley.
Pteromalus pallipes Forbes.
Eupelmus allynii French.
Entedon epigonus Walk. (Artificially introduced.)
PROCTOTRYPIDÆ.
Polygnotus hiemalis Forbes.
Platygaster herrickii Packard.

As secondary parasites we may record *Tetrastichus productus* Riley and *Tetrastichus carinatus* Forbes.

In Russia, Lindemann records the following:

CHALCIDIDÆ.
Merisus intermedius Lindm.
Entedon epigonus Walk. (*Semiotellus nigripes* Lindm.).
Eupelmus karschii Lindm.
Euryscapus saltator Lind. (Reared also from galls of *Isosoma hordei*.)
Tetrastichus rileyi Lindm. (Secondary parasite of *Merisus*.)
PROCTOTRYPIDÆ.
Polygnotus minutus Lindm.

In England, Miss Eleanor A. Ormerod and Mr. Fred Enock have obtained the following parasites:

CHALCIDIDÆ.
Merisus destructor Say.
Bœotomus subapterus Riley.
Merisus intermedius Lindm.
Entedon epigonus Walk.
Eupelmus karschii Lindm.
Euryscapus saltator Lindm.
Tetrastichus rileyi Lindm.
Tetrastichus (2 species).
PROCTOTRYPIDÆ.
Polygnotus minutus Lindm.
Platygaster herrickii Packard.

Marchal records from *Cecidomyia destructor* the following as being obtained from Vendée:

CHALCIDIDAE.
Merisus destructor Say.
Holcœus cecidomyiæ Ashmead.
Bœotomus rufomaculatus Walk.
Eupelmus atropurpureus Dalm.
PROCTOTRYPIDAE.
Polygnotus minutus Lindm.
Polygnotus zosini Walk.
Trichasis remulus Walk.

Before taking up in detail the species of parasites known to infest the insect in America, we may stop to notice the remarkable studies of Marchal upon the early development of some of the parasites as observed by him. The most striking of these relate to the early stages of *Trichasis remulus*, which is said to deposit its eggs in May and June, either in the egg or the very young larva of the *Cecidomyia*, the larvæ of the *Platygaster* being always encountered in the very young larva of the *Cecidomyia*. In some cases where the punctures by the parasite have been too numerous the larvæ attacked die and dry up without completing their development. In such cases the parasites are arrested in their development and perish. More often the Cecidomyian larva continues to feed and grow to the time of forming the puparium. The puparia of the attacked larvæ are smaller and paler than those of normal larvæ, sometimes even of minute size, generally very flat, and always of irregular form.

The course of development of the *Trichasis* has been very fully summarized by Howard * in his review of Marchal's paper, and I can do no better than reproduce the following extract:

According to Marchal the first larval form of *T. remulus* corresponds to the type of the curious cyclops-like larvæ studied by Ganin, and which certain authors regard as an adaptive form, while others see in it an ancestral form. The post-embryonic development, according to Marchal, is as follows:

When they are young and motionless and have not issued from the cysts which

* (Science N. S., Vol. VII, pp. 246–247.)

contain them, these larvæ are always lodged in the interior of the nervous system of the host larva, and there they bring about alterations and proliferations of a very curious character. The most frequent position is at the posterior of the extremity of the nerve chain, where the cyst of the parasite is formed. This extremity spreads out into an enormous bouquet of club-shaped, giant cells, which alone fills the larger part of the body cavity of the host. The larva of the parasite is lodged in a cyst filed with liquid, the cellular structure of which, with broad, polygonal contour, seems to indicate an amniotic envelope in a condition of retrogression. All around this membrane the giant cells are grouped. These exist not only in the immediate neighborhood of the cyst, but all the surrounding region of the nerve chain seems to have undergone the same degeneration and growth of giant cells. The youngest cells are hyaline, and present a fibrillous, longitudinal structure. The oldest cells are filled with fatty globules, and become entirely opaque. The giant cells increase and isolate vesicles, which separate and fall into the body cavity in the form of protoplasmic spherules, which are absolutely characteristic. When one dissects a Cecidomyid larva under the microscope he can be sure, if he sees these spherules floating in the liquid, that there are in the preparation one or more larvæ of this parasite. The localization of the larvæ of the Trichasis in the nerve chain or in the nerves of the larvæ presupposes that the parasite pierces the egg or the young larva upon the median line at the time when the nervous system has not begun to branch and is concentrated in a single ventral band. The mass of giant cells evidently accumulate in themselves the nutritive material necessary to the parasite. They are a kind of internal gall, developed by the presence of the parasite. The Trichasis, in the condition of the cyclops-like larva, waits in its cyst until the tissues which surround it have submitted to the transformations by which it profits later for its food; then, when the host larva, exhausted by its presence, is transformed into a sort of sac filled with giant cells, it issues from its cyst to devour the accumulated material, which, probably, has nutritive qualities nearly identical with those of the vitellus. After undergoing successive transformations into three larval forms the adult insect finally issues from the puparium of the host, only one adult finally making its appearance from an individual puparium, although in the cyclops stage four larvæ may be present. There seems in this first stage to be a physiological competition between Trichasis larvæ, only the oldest surviving to take on the second stage. An interesting point is that there appear to be definite molts from the first to the second and from the second to the third stage, and that the dead bodies of the cyclops larvæ which succumb do not interfere with the development of the survivor.

Another species to which Marchal has given careful study is the *Polygnotus minutus* Lindm., and which he has localized in the stomach instead of the nervous system. As many as ten or twelve were found grouped together and developing simultaneously, and destined, all or nearly all of them, to complete their development.

Quoting again from Howard:

The group of young larvæ forms a mass situated in the interior of the stomach. It is surrounded by a hyaline and perhaps adventitious membrane. Each parasitic embryo is also surrounded by a membrane of its own. The larva is elliptical, somewhat attenuated at its posterior extremity, and provided with rather well-devoloped mandibles. They fill the gastric cavity, which is generally distended. The second and third larval forms follow. The host is almost entirely devoured and reduced to a cutaneous sac. When ready for pupation they occupy the entire body cavity of the host, the skin being distended and showing by impressions the positions occupied by the contained parasites, thus appearing full of minute cocoons.

These facts have particular interest as showing the effect of the parasite on the tissues of the host, and the most remarkable point perhaps is the formation of the giant cells with Trichasis, indicating a process of gall formation in these tissues analogous to the gall formations produced in plant tissues by the presence of various insects or insect larvæ.

Merisus destructor Say. (Fig. 2.)

This species, first characterized by Say as *Ceraphron destructor*, is doubtless the most universally important of the Hessian fly parasites, as it occurs not only throughout the American territory affected by the Hessian fly, but is known also in England and continental Europe. It has received notice from nearly every writer on the Hessian fly since its first description, and Dr. Riley has given a full statement of its synonymy and a discussion of its relation to *subapterus*, but no author has given us the knowledge of its early stages or the relation it bears in development to that of its host that is desirable in its practical treatment with reference to securing most advantage from its work. Riley says:

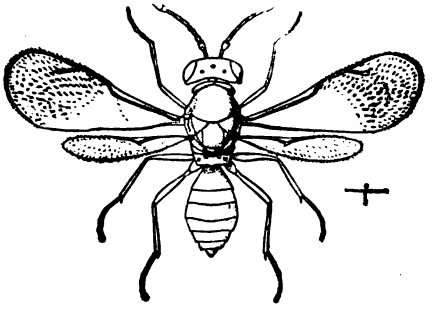

FIG. 2.--*Merisus destructor* (from Riley).

The eggs of this parasite are without much doubt deposited in the half-grown larvæ of the Hessian fly early in the spring, and in the more southern portions of the wheat belt there are in all probability two generations, the first issuing from the puparium in April and May and the second issuing all through the summer and fall. Many, judging from my experience indoors, hibernate in the pupal stage within the Cecidomyid puparium and cut their way out the following spring. In the North, however, there seems to be but one annual generation.

In Iowa, as we have noted, there is an emergence of adults in early autumn, and either these must be able to deposit eggs or else live over winter as adults, otherwise they must perish without providing for another generation.

Marchal refers to this species certain larvæ encountered in the larvæ of Cecidomyia, and characterizes them as glabrous and full, the larvæ being very different in appearance from the normal occupants of the puparium.

The following detailed description is by Dr. Riley, in Proceedings of the U. S. National Museum, volume 8, page 415:

Male.—Length (average) 1.98 mm. Greatest width of fore wing, 0.62 mm. Antennæ long filiform, strongly pilose; funicle joints subequal in width, decreasing slightly in length from 1 to 6; joint 1 a little more than twice as long as broad; the club is nearly as long as the two preceding joints of the funicle together, ovate, flattened on the sides, and acuminate at tip. The ocelli are large and prominent. Head and notum densely and rather finely punctate, the punctures on the mesoscutellum and

metanotum finer than those on the head, pronotum, and mesoscutum, those on the metanotum being deeper; metanotum with an indication of a median carina. The abdomen is oval, convex above, flattened below, glabrous, but very finely shagreened. The hind tibiæ have but one apical spur, and the hind trochanter has two very minute tooth-like projections below. General color black; antennal scape yellowish, pedicel and flagellum brown to blackish, pedicel often yellowish below; head and thorax with a bluish, green metallic reflection; all coxæ black with metallic reflections; all femora black or dark brown, with yellowish tips; all tibiæ and tarsi honey-yellow. Wings perfectly hyaline; wing veins very distinct, dark brown in color; spurious veins more distinct than in *M. subapterus*. Abdomen black with a yellowish spot varying in size above and below at base.

Female.—Averages in size a little larger than the male, from which she differs principally in the antennæ, which are short and have a slight clavate tendency; the funicle joints increase slightly in length from 1 to 6; club short and obliquely acuminate; scape short, light yellow-brown in color; flagellum brown; club lighter in color than the remainder of the flagellum; pile very short and fine.

Described from 4 males, 10 females.

Differs from all other described species of the genus in the combination of the pale scape, hyaline wings, and flattened abdomen.

Bæotomus subapterus Riley. (Fig. 3.)

Pteromalus? fulvipes Forbes.

Wingless male.—Length varies from 1.58 to 2.74 mm. Antennæ inserted a little below the middle of the face, their bases close together, but still distinctly separated; scape reaching to the ocelli; flagellum short, finely pilose, club oval, acuminate, flattened laterally; joints of the funicle subequal in length, joint 1 a trifle longer than broad, the rest increasing very slightly in width to joint 6, which is as wide as long. Cheeks well rounded; ocelli in a curved line, middle ocellus indistinct; head considerably broader than thorax, densely and finely punctate. Pro- and mesonotum with punctation similar to that of the head; metanotum rounded, with somewhat larger and deeper punctures. Abdomen ovate, acuminate, not flattened, perfectly glabrous. Color: Head and thorax with a dark-greenish metallic luster; bulla of antennæ black, scape and pedicel honey-yellow; flagellum yellow-brown, often with a darker metallic tinge, especially at the joints, causing the flagellum in some instances, particularly in the smaller individuals, to appear dark; pile whitish; all legs honey-yellow, coxæ very slightly metallic at base; tarsi, and sometimes distal end of tibiæ, whitish; abdomen black; penis (often extruded to a considerable length) brown.

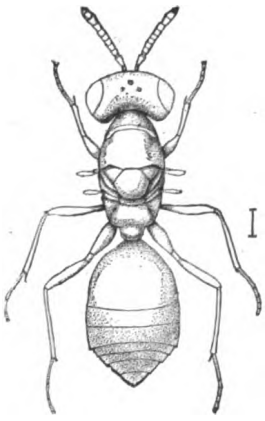

FIG. 3.—*Bæotomus subapterus* (after Riley).

Female (*winged and wingless*).—Length varies from 1.8 to 2.8 mm.; average wing expanse, 3.75 mm. Differs from male in the following respects: The antennæ are more clavate, the sixth funicle joint slightly broader than long; the flagellum is always black, with a slight metallic tinge, and the pedicel is usually tipped with black at its distal end; the pile is much shorter and finer than in the male. The femora and the tibiæ are in general of a darker brown, in which case the knees and the distal third of the tibiæ are whitish. The metallic luster of the thorax is more subdued, and the abdomen has the characteristic female notch when seen from the side. The wings are perfectly hyaline, and the veins are only faintly tinged with yellowish; the spurious veins are very faintly perceptible.

Described from many male and female specimens, only three of the latter being winged. All bred from final larva of the Hessian fly collected at Cadet, Mo., by J. G. Barlow, and issuing through the coarctate larva shell.

Distinguished from other described species by the contrasting antennæ in the sexes and by the ovate abdomen which, when fresh, has no flattened dorsal surface.

This species is probably, next to *destructor*, the most important of the Hessian fly parasites. Indeed, Dr. Riley has stated that the relative abundance of this and the preceding species is probably a question of latitude or location, and this species has been bred much more commonly than *destructor* from infested wheat from Missouri. The winged and wingless individuals are considered as certainly belonging to the same species, and the proportion of winged to wingless individuals is said to vary at different seasons of the year. "Thus, from a lot of puparia of the Hessian fly, received in the summer of 1883 from Missouri, there issued 31 wingless males, 28 wingless females, and 3 winged females. Of these about one-third issued from the straw in August, 1883, and the rest, including all the winged individuals, hibernated in the straw and issued in April and May, 1884."

From this it would appear that we may have much the same retardation of development in the parasite as in the host, and that the appearance of adults in autumn or in the following spring may be a matter of conditions.

Pteromalus pallipes Forbes.

A short, thick species, with the head broader than the thorax, the abdomen ovate and obtuse. Head and thorax bronzed black, thickly set everywhere with punctures of medium size. The occiput and the dorsum of the thorax with a few scattered appressed hairs. The front of the head is vertically grooved for the long, first joints of the antennæ. Eyes pale red, mouth-parts brown. The antennæ are about as long as the head and the thorax, thirteen jointed, the first joint pale yellow, second joint dusky, the remaining joints black. The first joint is about equal in length to the four following, the third short, that and the fourth together shorter than the second and about equal to the fifth, the joints widening from the first to the fifth (except the third, which is not wider than the second), the following joints, to the eleventh, of about equal diameter, thence tapering rapidly, the last three not being clearly distinguished. The first joint is nearly smooth, the second somewhat hairy, all the others black pubescent, each with a transverse ring of long appressed yellow bristles. The mesoscutellum is broadly rounded behind, the sides with an irregular excavation, the metascutellum with an elevated margin and an evident median carina. The sides of the metathorax are densely clothed with long black hairs.

Wings transparent, veins dusky yellowish, the post-costal and stigmal of equal length, about two-thirds as long as the costal. Wing membrane sparsely pubescent, the veins with a row of stiff, erect black hairs. Patagia dusky yellowish.

The legs are pale yellow throughout, except the coxæ, which are of the body color. The abdomen is smooth and shining, except the under sides of the three posterior segments, which are pubescent. It is black above and piceous beneath, the edges of the segments being somewhat tinged with brown.

Length, 2.5 mm.; head, 0.95 mm. wide; thorax, 0.7 by 1.06 mm. long; antennæ, 1.25 mm.; wing, 1.9 mm.

Eupelmus allynii French. (Fig. 4.)

Professor French, who was the first to describe this species, at first believed it to be a wheat pest, but subsequent study and the observations of Drs. Riley and Forbes have established it as a parasite of the Hessian fly, with a number of other forms.

The fact that it lives on other insects is a point in its favor, as this enables it to survive during years when the Hessian fly is wanting or very scarce.

Professor French's description is as follows:

Male.—In this sex the body, wings, and antennæ are colored like the females, but the antennæ are a little more slender at their ends. The head and thorax

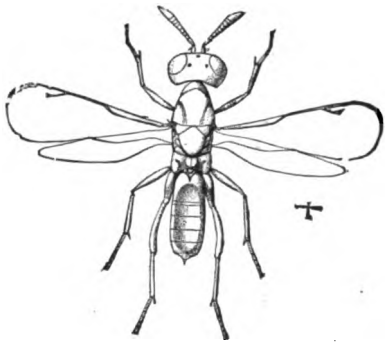

FIG. 4.—*Eupelmus allynii*, male (after Riley).

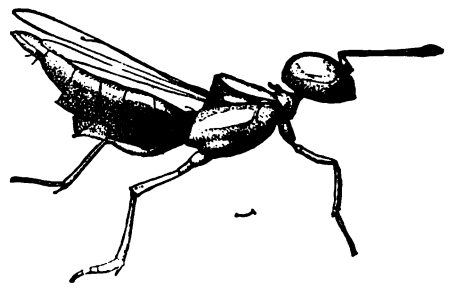

FIG. 5.—*Eupelmus allynii*, female (from Riley).

have about the same measurements, but the abdomen is a little shorter, the whole insect being from 0.06 to 0.07 of an inch. The legs have all the femurs yellow, front tibiæ yellow, middle and hind tibiæ fuscous, except at the apices, which are yellow; feet as in the females.

Female.—Average length, 0.10 of an inch. Color of body and antennæ uniform black, the first with a slight greenish luster. Head about 0.025 of an inch wide, about two-thirds as long; the antennæ a little enlarged at the ends, hairy, microscopic hairs moderately scattered over the head and thorax. Thorax, as well as head, punctured; wings hyaline, dotted over with microscopic hairs, the thorax in its widest part about the width of the head. Abdomen gradually tapering from near the base, the ovipositor slightly exserted. Color of the legs varies slightly; in five specimens the anterior and posterior legs have the femurs fuscous except at the ends, the tibiæ with basal half fuscous, the rest yellow; the terminal joints of tarsi fuscous; the middle pair of legs are yellow throughout except the terminal tarsi. Two specimens have all the femurs fuscous, yellow at the ends. One specimen has all the femurs pale red and the tibiæ fuscous, but this is probably a change from yellow by the poison bottle used in killing. One is marked like the first five, with the yellow replaced by pale red; another is like the first five, except that the middle tibiæ are a little clouded at base.

According to the breeding records of Professor Forbes, this species issues during June and July, especially from June 13 to July 18.

Platygaster herrickii Pack. (Fig. 6.)

This parasite has been obtained from the Hessian fly and is counted one of the common species infesting it. It was credited with puncturing the egg and laying its egg within to hatch later and consume the larva. This was considered as a very improbable method of attack, as the true egg parasites were known to complete their life cycle within the egg itself.

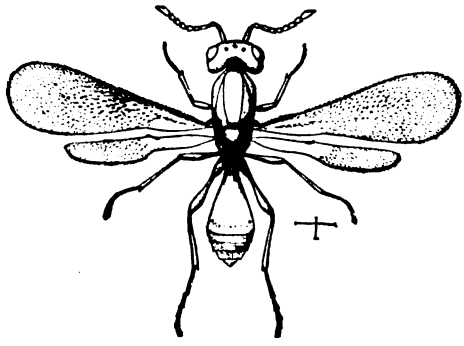

FIG. 6.—*Platygaster herrickii* Pack (after Riley).

The observations of Marchal on Trichasis have, however, shown the probability of such a mode of attack in that species, and so there would seem a possibility of such habit for this. If occurring in the fall and affecting particularly the larvæ living in winter wheat, it will be seen that it operates at a season when the Merisus is most inactive.

This is a very minute species, being only 1½ to 1¾ of a millimeter in length. It is described as black, shining, finely punctate; the antennæ 10-jointed, black; the wings veinless, or with a submarginal vein appearing as a yellowish streak.

Polygnotus hiemalis Forbes.

Platygaster hiemalis Forbes, Psyche, vol. 5, p. 39 (1888.)

Male and female.—Length, 0.80 to 1.40 mm. Black, polished; head about two and one-half times as wide as long anterio-posteriorly, the vertex posteriorly only faintly aciculated, the face smooth, polished. Antennæ 10-jointed, brown black, the flagellum twice as long as the scape; pedicel as long as and much stouter than the first two funicular joints; first funicular joint small, not longer than thick, yellowish basally; second larger and a little longer than the third; club 5-jointed, the joints, except the last, a little longer than wide, the last cone-shaped, one-half longer than the preceding. In the male the second funicular joint is thickened, curved, and as long as the pedicel, the latter whitish or yellowish at the tip; the funicular joint small, contracted at base; club 6-jointed, villose, the joints oblong, slightly pedicellate, the first, the shortest, narrowed basally, the last ovate, not quite twice as long as the penultimate. Thorax ovoid, polished, the mesonotal furrows delicate but distinct posteriorly; in the male almost obliterated, the middle lobe projecting slightly upon the scutellum. Scutellum very high, transverse, convex. Metapleura subsericeous. Tegulæ rufo-piceous. Wings hyaline, pubescent. Legs dark brown to piceous, trochanters, tips of anterior femora and tibiæ, base of middle and posterior tibiæ, and all tarsi, brownish yellow or honey yellow, sometimes the posterior femora black. Abdomen in the female about as long as the head and thorax together; in male shorter; in both sexes the petiole and the foveolæ at base of the second segment striated.

Habitat.—Western States.

This species seems to have been first reared by Dr. Riley from specimens of the Hessian fly (*Cecidomyia destructor* Say) August 16, 1876, received from Blair, Nebr. It has, however, since been bred from the same fly by various persons in the Western States. Professor Forbes reared it in 1888 at Champaign, Ill.; Professor Cook, of the Agricultural College of Michigan, in 1890, and Professor Webster, at Laporte, Ind., in 1889.

I know of no specimens reared in the Eastern States. Can it be a species moving eastward? (Ashmead.)

Lygocerus triticum Taylor.

Ceraphron triticum Taylor, Am. Agric. 1860, p. 300, f. 1; Cress. Syn. Hym., p. 248.

Lygocerus triticum Taylor, Ashmead, N. Am. Proctotrypidæ, p. 110.

This fly does not correspond with the above (*Ceraphron destructor* Say), therefore I have named it *triticum*, from the botanical name of wheat. It is not of such a shining black as Mr. Say's fly, but is rather rusty in appearance, from a few hairs scattered over its body. In some specimens, when very fresh, the legs have a bright tinge of yellow. The antennæ (*b*, fig. 2) are termed setigerous (having the basal joint large) and the last four globular, the intermediate one furnished with four long bristles resembling plumes. This is a very sure mark for distinguishing this family according to European classification. The eyes are large in proportion, the palpi 3-jointed. The fore wings have submarginal cells, with a faint nervure running to apex. The under wings have a long nervure running through and two smaller ones descending to the inferior region; these are so very slight that you can only see their existence by a deep shade of the wings in a strong light, but are evidently nervures, indistinct as they are. The ovipositor is retractile and tubular. The fly deposits her eggs in the pupa of the Hessian fly. (Taylor.)

Unknown to me, and the above description is copied from the American Agriculturist. Miss Taylor further informs us that "this fly can be found in every wheat field throughout the country, from spring to autumn." Her description is very imperfect, and her figure of the male antenna strongly recalls the branched antenna of an *Eulophus*. (Ashmead.)

The above reference, quoted from Ashmead's "Proctotrypidæ," gives all that appears to be known concerning this species.

SECONDARY PARASITES.

Aside from the parasites attacking the Hessian fly directly, there are species which attack their parasites and are called secondary parasites. These, of course, by reducing the numbers of the primary parasites, operate to the disadvantage of the cultivator. Two species have been described in this country, both in the genus Tetrastichus.

Tetrastichus productus Riley. (Fig. 7.)

Male.—Average length, 1.5 mm.; wing expanse, 2.6 mm.; greatest width of the fore wing, 0.5 mm. Scape somewhat broadened below, inserted near the middle of the face in a deep groove, and reaches nearly to the ocelli. Flagellum long, flattened, hairy, each joint except club with a whorl of long, slender hairs at base. Funicle joints twice as long as wide. Head considerably shrunken after death. Head, pronotum, and mesonotum smooth and shining; metanotum, pro, meso, and meta pleura, and all coxæ above finely punctate. Submarginal vein of the fore wing with a single stout superior bristle behind its middle; marginal vein three times as

long as stigmatal; post-marginal wanting. Median impressed line of mesosternum very distinct; metanotal carina distinct, rather short. Abdomen narrow, compressed laterally, subacuminate. General color shiny black, with slight metallic reflections; flagellum, brown; all trochanters, distal end of all femora, all tibiæ, and tarsi honey yellow; wing veins, brown, very distinct.

Female.—Length (average), 2.1 mm.; wing expanse, 3.2 mm.; greatest width of fore wing, 0.55 mm. Scape slender, pedicel ovoid, ring joints very small; flagellum rather short, but slightly compressed; club ovate; funicle joints subequal in size, joint 3 rather shorter than 1 and 2, its length exceeding its width but slightly. Abdomen narrow, flattened dorso-ventrally, prolonged to an acute tip.

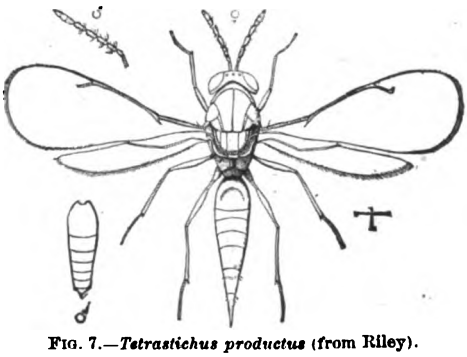

FIG. 7.—*Tetrastichus productus* (from Riley).

Described from six males and seven females.

Tetrastichus carinatus Forbes.

A slender, smooth, dark steel-blue species, 2 mm. in length, with pale legs, 4-jointed tarsi and 8-jointed antennæ.

The head is very short, not wider than the somewhat slender thorax, impunctured, as are also the thorax and the abdomen. Eyes large, dark red, broadly elliptical, occupying the whole longitudinal diameter of the head and even encroaching upon its posterior surface. Front broadly bisulcate for the reception of the scapes of the antennæ. Antennæ short, 8-jointed, joints very distinct, except those of the ovate club (three in number), which are very closely compacted. Second joint shorter than the third, which is longer than the fourth and fifth, these being subequal. First and second joints of the club nearly equal, thicker than the preceding. Flagellum of the antennæ pale, provided with a few erect, black hairs and long appressed yellow ones.

Prothorax is very short; the mesoscutum very long, narrowing posteriorly, where it is broadly truncate against the scutellum, regularly convex, minutely carinate longitudinally on the middle line; parapsidal grooves complete. Scutellum vaulted, with two longitudinal carinæ. Abdomen of the female pointed, ovate, broadest in front of the middle, somewhat flattened above.

Legs rather long, pale yellow; fore tarsi dusky, middle and hind tarsi dusky at tip; all the tarsi 4-jointed, first joint of front and middle tarsi shorter or no longer than the second, that of hind tarsi longest of all.

The entire surface is very sparsely provided with coarse, yellowish hairs, longest and most numerous at the tip of the abdomen.

Costal vein very stout, provided with unusually long hairs; stigmal vein short; postcostal nearly obsolete; no trace of median or submedian.

This species was bred in our breeding cages from the collections made at Anna, June 24. (Forbes.)

UTILIZATION OF PARASITES.

It may seem hardly necessary to devote so much attention to the parasites of an insect if it is not possible to so use them as to secure some practical control of the pest. That this can be done by the proper recognition of the time of emergence of the parasites seems at

least extremely probable, although there is yet too little evidence as to the issuing of parasites at times when the development of the host is retarded to warrant positive assertions. That the parasites do in some seasons issue with much less moisture than is necessary for the development of the host seems almost certain, and there is sufficient basis in this to delay the burning of stubble during dry summers until the parasites have had time to issue.

There is another direction, however, in which the parasites may be employed, which is of interest more particularly to localities that have been recently invaded or where the parasites are not present.

We have already seen that the regions where the Hessian fly is most widely distributed contain a goodly list of parasites, and such as would appear to occupy about the same position with reference to the host. We may easily conceive, however, of the introduction of the Hessian fly into a new territory, such as isolated wheat districts in Oregon or Washington, without the parasites accompanying them.

In such cases there would be very evident advantage in the prompt introduction of parasitized puparia and the setting free of the parasites so they might establish themselves. Another direction for effort is the introduction of species not found in one country but which are common in another. Thus the introduction into this country of species common in Europe but not found here would add to the effective agents in control by whatever portion of the history of the species might be exposed to the attack of this species not open to the parasites already present; and that the different parasites work at different times or in different ways is hardly to be doubted.

Introduction of Entedon epigonus.

One of the most promising efforts at introduction of the parasites occurring on the Hessian fly in the Old World was made in 1891, by Dr. C. V. Riley, who received pupae parasitized with *Entedon epigonus* (*Semiotellus nigripes*) of Russia from Mr. Fred Enock, of England. These were distributed to Prof. S. A. Forbes, in Illinois; Prof. A. J. Cook, in Michigan, and Prof. F. M. Webster, in Indiana. The report of results given by Professor Forbes is worthy of reproduction. I am not aware that any reports of the other introductions have been published. Professor Forbes's report, taken from Insect Life, Vol. IV (p. 179), is as follows:

> According to my promise I submit the following account of a recent experiment, begun at your instance and with material furnished by you, for the transfer of a European parasite of the Hessian fly to the United States.
>
> In accordance with arrangements made by telegraph, I received from you May 6 a package of Hessian fly puparia, said to have been parasitized by the European species *Semiotellus nigripes*, and with this package a letter from you asking me to take charge of and liberate the parasites in an inclosure of infested wheat, with an idea of introducing the species. A second package came two days later, accompanied by a letter of advice from your assistant, Mr. Howard.

I had growing at the time under gauze, but otherwise in the open air, a small plot of badly infested wheat, 2½ by 3 feet, in very fortunate condition for the experiment. This wheat had been transplanted March 26 from a field near Roodhouse, in Morgan County, for use in making observations on the life-history of the Hessian fly, and contained when transferred large numbers of the insect in the hibernating puparium. Male and female adults had begun to appear in the inclosure by April 1, and these transformations continued to May 13, the greater number of them occurring about April 20, when, for a few days, more than twenty adults could be counted in the cage at a time, not to mention others doubtless concealed in the wheat.

The first lot of foreign parasites was exposed in this cage May 7, and the second lot May 11, both packages containing living adults when opened.

At the time of the first introduction eighteen of the wheat stalks were examined, and fifteen young larvæ of the Hessian fly were found upon them, and all the conditions were thus favorable to the success of the experiment. Four days after the introduction of the parasitized foreign material five freshly emerged specimens of *Semiotellus nigripes* were noticed in the cage, and others appeared May 13, June 29 and 30, and July 1, 3, 9, and 14. On the date last mentioned the wheat in the cage was overhauled and the puparia were removed and divided into three lots; one to be kept at the office for regular observation of the transformations, one to be taken into southern Illinois and distributed through fields of stubble containing Hessian fly puparia, and a third to be sent, in accordance with your letter of July, to Mr. James Fletcher, Dominion entomologist, Ottawa, Canada.

The parasitized puparia received from Washington were all spent by this time, or, perhaps, some time before. Removed from the cage July 18 they were kept until October 7 without the appearance of another parasite insect. Parasites of the new generation continued to emerge from the lot kept for observation until August 29, the exact dates being July 16, 18, 21, 23, 24, 27, 31, and August 1, 6, 10, 12, 16, 20, 23, 25, and 29.

Most of these were released in a field of moderately infested wheat stubble on the experimental farm of the agricultural experiment station at Champaign, beginning with 4 specimens July 22, and adding 13 on August 1, 18 on August 6, 23 on August 10, 15 on August 12, and 4 on August 20; 77 adults in all having been thus released at this place.

In the meantime measures had been taken to introduce the parasites on a larger scale in southern Illinois. Taking with me about two-thirds of the material obtained from our breeding-cage experiment—the parasitized puparia still in the straws—I traversed several counties from Centralia south to Union County, and thence to St. Louis and Jacksonville, stopping at intervals, but finding no satisfactory situation until I reached Scott County, July 17. On the farm of Messrs. Edward and Frederick Vantyle a field was found 3 miles northeast of Roodhouse, the yield of which has been reduced by the Hessian fly from about 30 to 35 bushels to the acre to 15. It was the only field in the immediate neighborhood which had been so damaged, and in this one the fly had not been noticed the year before. There was, consequently, little probability of excessive native parasitism of the succeeding brood, and it seemed likely that the fly would occur there this fall in volunteer grain and later in the regular sowing.

The owners agreed to leave unplowed a piece of stubble, on which my specimens were scattered, while the remainder of the field was to be plowed for wheat within a few days. The fact that specimens of the *Semiotellus* continued to emerge from the check lot retained at Champaign for some weeks after this distribution is evidence that a considerable number of the parasites must have gone abroad in Scott County. Indeed, forty or fifty of them, which had completed their transformation en route, escaped from the box when it was opened in the field.

It will be seen from the foregoing narrative that we succeeded completely in breeding a generation of the foreign parasite in our plots of wheat infested by the Hes-

sian fly, and that these bred insects were successfully distributed to fields infested by the fly at two places in Illinois—in Champaign and Scott counties, respectively.

It should be said, in conclusion, that the latter part of the summer was exceedingly dry throughout central Illinois, and that as a consequence but little volunteer grain grew in either of the above localities, and that neither in this nor in the early sown wheat was there any considerable amount of Hessian-fly attack—circumstances which are to some extent unfavorable to rapid success of the experiment for the introduction of this parasite. The Vantyle farm was visited by my assistant, Mr. Marten, September 24, at which time the plowed portion of the field was being drilled to wheat. Along the margins of this plowed ground, near the plot which had been left in stubble, was a scanty growth of volunteer wheat, in which, after considerable search, four nearly full-grown larvæ of the Hessian fly and one fresh puparium were found. Little other volunteer wheat was seen in the neighborhood. A brief search of the stubble remaining showed only parasitized puparia from which parasites had already escaped.

The Champaign County plot was examined September 30, when one hundred and

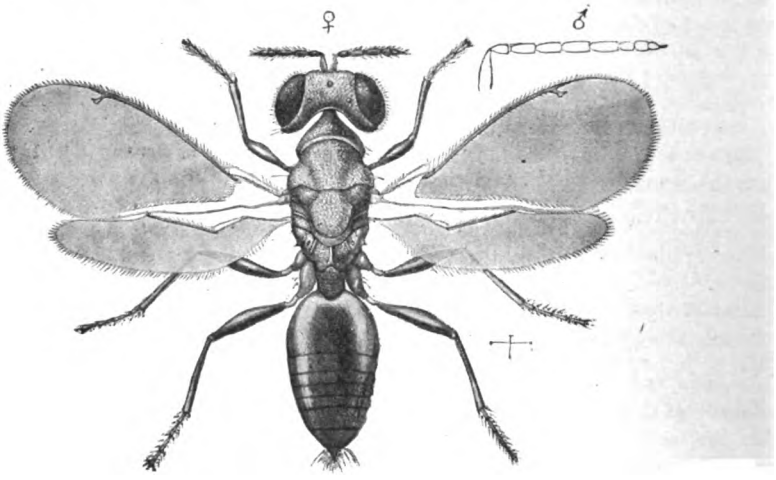

FIG. 8.—*Entedon epigonus* (from Howard, in Insect Life).

twenty plants of volunteer wheat grown in the experimental stubble field were overhauled. In these plants two larvæ and seven puparia of the Hessian fly were found. October 5, from forty-three plants eight puparia and two nearly full-grown larvæ were taken. As the period of the emergence of the imported *Semiotellus* was substantially the same as that of the native *S. destructor*, the two coming out side by side in our breeding cages, it seems practically certain that the imported parasite must have had as fair a chance for propagation in the field as its native congener.

We will of course keep careful watch of these localities next year, and will notify you of any observations then made bearing on the reappearance and the spread of this imported enemy of the Hessian fly.

The results of the introduction in the vicinity of Washington are recorded by Dr. Howard in Insect Life, Vol. VII, page 414, as follows:

In the last number of Insect Life (p. 356) we published a figure of *Entedon epigonus* (fig. 8), the principal European parasite of the Hessian fly, and mentioned the attempts which Professor Riley had made in 1891 to introduce the species into the wheat fields of this country. One of the last acts performed by Professor Riley before leaving this office in May, 1894, was to send a batch of parasitized puparia of

the Hessian fly, just received from Mr. Fred Enock, of London, to the farm of Mr. G. Morgan Eldredge, at Cecilton, Md. During May, 1895, wishing to ascertain whether or not this attempt had been successful, we sent Mr. William H. Ashmead to Cecilton to make careful observations. He found that the parasitized puparia had been placed upon the ground at the borders of a field which appeared to be rather badly affected by the Hessian fly. The crop was harvested and the land plowed at the end of August and planted in winter oats, which at the time of Mr. Ashmead's visit were from 4 to 6 inches high. After harvest the wheat straw was stacked in the immediate vicinity of the place where the parasitized puparia were deposited, and a small quantity of winter wheat was sowed (during August), so that the Hessian fly might find an early place for oviposition, giving the parasites a good chance. Mr. Ashmead swept volunteer wheat in the immediate vicinity of the straw stack, and also swept the adjoining field, at that time in winter wheat. He was in the field but a single day, and among the lot of parasites which he took from his beating net, and which consisted mainly of one of our most common American parasites of the Hessian fly, *Platygaster herrickii* Pack., was found a single male specimen of *Entedon epigonus*.

The presence of this single living specimen indicates that the parasite has established itself to a certain extent, and it is greatly to be hoped that subsequent visits will show it to be present in numbers.

OTHER NATURAL ENEMIES.

Nematode worms.—Marchal has called attention to the occurrence of nematodes in the infested straws and even in the puparia of the Hessian fly, but never in the larvæ themselves, although the appearance of the latter would indicate destruction by the worm. Whether this is a normal parasite of the Hessian fly may be questioned, but that the worms might easily destroy such larvæ as they came in contact with would seem very possible.

Thrips.—Both Mr. B. D. Walsh and Mr. Theo. Pergande have expressed the opinion that the Cecidomyia may be attacked by thrips, but so far as I am aware no demonstration of such attack has been made. Their remarks on this subject have been republished in volume I of Insect Life, pages 138 and 139.

REMEDIES.

While investigations of recent years can hardly be said to have added any absolutely new methods of treatment, it is evident that more precise knowledge of the life history and especially of the variations in time of appearance and number of broods does enable us to state with much greater confidence the conditions under which certain measures are available. Knowing the conditions affecting acceleration and retardation of development, it becomes possible to specify the appropriate occasion on which to resort to burning, plowing under, delay of seeding, etc., and it will be our effort in the following discussion of remedies, most of them of long recognition, to so state the conditions under which each may be most effective that the cultivator himself, without having to call in a professional entomologist to examine the field, may act intelligently.

In fact, we have the authority of Professor Webster for the statement that the Hessian fly need be no longer a source of loss under a proper system of agriculture. That the farmer, however, be best prepared to contend with the insect involves for him a thorough knowledge of the conditions favoring or obstructing the action of the insect, and to this end he should be particularly familiar with the conditions of acceleration or retardation of development as affecting the time of appearance of the various broods.

Probably the most important measures available with our present knowledge are those directed against the insect in its summer resting period or the early issuing flies of late summer and early autumn.

BURNING THE STUBBLE.

This remedy has been one of the standard measures from very early times, and while objection has been raised to it on account of the fact that the parasites will be destroyed along with the Hessian fly, it may be considered as one of the most generally applicable. To be effective, the burning must be performed before the flies have had an opportunity to emerge, but in this respect there is little danger of being too tardy unless unusual moisture accelerates the emergence of the flies. Postponement until the parasites have had an opportunity to emerge would, in fact, be an advantage, and, during dry weather in July and August, the firing may be postponed. In some cases the burning is made more effective by cutting the wheat pretty high, so as to leave a larger amount of stubble, thus insuring a more rapid spread of the fire. It has the further advantage of leaving with the stubble any chance "flaxseeds" which may occur higher up on the stalk than the usual position.

An objection to burning, which has been suggested by Lindemann, and is supported by Marchal, is that under a given climate it may be that at the time of harvest a considerable part of the puparia will have already matured and the flies issued, so that those destroyed will be simply an insignificant part that have been delayed in their development, and their destruction, while useful, would be so in but a slight degree. The determination of the condition of the "flaxseeds" would be difficult except by examination by an expert entomologist, and treatment with reference to this point is rather impracticable. So far as the American wheat grower is concerned, it would seem unwise to use this objection, as the benefit in general from burning infested stubble is so great that other considerations may be overlooked. The main point is to determine the time of movement, and this in general should be as soon after harvest as the conditions of the season are likely to cause the emergence of flies.

Along with the burning of the stubble we may call attention to the desirability of burning chaff and screenings after threshing, as Miss Ormerod has pointed out that many puparia are to be found in these

materials. While probably less useful in this country where the straw is of less value and is not cut so close to the ground, the fact that we have here a possible source of danger is sufficient reason to take the small trouble necessary to guard against it.

THE PLOWING UNDER OF STUBBLE.

Next to burning, and available when burning is impracticable, the plowing under of stubble is perhaps most important. To be most effective the stubble should be turned to the depth of several inches and the field rolled, so as to compact the earth and prevent the issuing of the flies which may develop from the puparia in the ground. The time of plowing depends upon the condition of the season, and here the conditions which suggest plowing in ordinary farm practice are those which best apply to the destruction of the insect. If the season be dry, the necessity for plowing does not exist, as the great majority of the insects will remain in the dormant condition, and those which hatch will fail to find food plants upon which to deposit eggs upon which the larvæ can feed. With the occurrence of rains, which put the ground in suitable condition for plowing, there is probability of an early emergence of flies, and further, of the springing up of volunteer wheat to furnish their progeny with necessary food.

In this connection it may be mentioned that where the crop is so seriously infested that it is not considered worth harvesting, it may pay to plow it under as early as possible, roll thoroughly, and plant to corn or other late crops. This method was adopted with excellent results by some farmers in the spring-wheat region of northern Iowa.

DESTRUCTION OF VOLUNTEER WHEAT.

It is evident that if all the food supply for insects during late summer and early autumn is destroyed, the flies emerging during this period will be unable to deposit eggs or their larvæ to develop. The volunteer wheat around stacks or through the fields, if present in any quantity, should be plowed under so that this source of food supply may be cut off.

PLANTING OF DECOY STRIPS.

Many authors recommend the planting of narrow strips of wheat in the field as decoys, but the plan has apparently been little used by farmers. This is perhaps because it entails extra labor and expense and presents only possible advantages. Professor Webster considers that while it is hardly possible to entrap the major part of the fall brood of larvæ, it is certainly possible to entice to these plats the stragglers and interlopers, which have been known to be capable of considerable injury. While the pest can not be exterminated in this way, its power to commit serious injury may be considerably weakened. Volunteer wheat would apparently serve the same purpose if appearing

early enough to attract the flies, and should in any case be plowed under as deeply as practicable. The proper time for sowing decoys will vary with the latitude. According to Webster, for northern Indiana they should be sown during the latter part of August, and in the southern part of the State not later than the first week in September. To the north and south of this he does not undertake to give dates, but it would depend upon the date of appearance of the fall brood of flies, the wheat being planted early enough to attract the flies at the time of their emergence. A decoy crop should be destroyed within four weeks at the utmost, and turned under so deeply that any insects maturing would be unable to escape.

EARLY OR LATE SOWING OF FALL WHEAT.

In winter-wheat regions the time of sowing in autumn is, with reference to the Hessian fly, a very important item. Early-sown wheat will naturally be exposed to the deposition of eggs by flies issuing in the autumn, but, on the other hand, if the plants have got well started and thrown out numerous tillers there is much less danger of their complete destruction, and if the flies should not be numerous a considerable gain may result. The principal objection to this view would seem to be that the multiplication of the insect is encouraged and there would be a strong probability of more serious attack the following spring. Early sowing may be practiced if desired, especially on a small scale, and then if it is found that the crop is considerably infested it may be plowed under the same as a decoy crop and the field resown later.

Late sowing of fall wheat has been one of the principal resources against the Hessian fly, and the writings of most of the leading entomologists have agreed in a strong recommendation of this policy. Packard quotes numerous writers in support of this general plan, and it appears to be very generally adopted by farmers. To be successful the sowing should be late enough so that the plants do not appear above ground until after the bulk of the Hessian flies have issued and died. It has been shown, however, that the flies may emerge quite late in the season and deposit eggs even after frosts are common. Marchal remarks that in Vendée the wheat sown after October 20 has been completely free from injury. In the practical use of this remedy it becomes essential for the farmers of any given latitude to determine the time of appearance for the bulk of the autumn brood of flies and to time the late sowing accordingly. This will be a progressive date from north to south. Webster says:

> If farmers in the extreme northern part of Indiana and in southern Michigan can sow their wheat with safety about the 12th to 15th of September (and we have demonstrated that the fall brood emerges largely prior to the 15th), and farmers in the extreme southern part of Indiana delay sowing until after the first days of October, there must be a general system of retardation which, if understood, may be used to advantage throughout the intervening territory.
>
> Starting in southern Michigan on the 12th or 15th of September and passing 4

degrees south to the vicinity of Evansville, Ind., we should expect about the same condition of the Hessian fly during the first week of October; that is, if we pass the danger line about the second week of September in southern Michigan, we should expect to encounter it again in southern Indiana in the first or second week of October. A considerable correspondence and my own experiments indicate that this is easily true.

Evidently there will be considerable seasonal variation, so that these dates must be taken subject to slight changes in either direction, but it may be assumed that the earlier or later appearance of the brood will depend upon the character of the season in moisture and warmth, so that if the weather remains unusually dry and hot the fall planting should be proportionately delayed, while if conditions favor an early emergence a crop may be planted somewhat earlier. Taking the latitudes mentioned as a guide, the farmers of the winter-wheat belt through Illinois, Missouri, southern Iowa, Nebraska, and Kansas can determine pretty accurately as to the proper time for seeding.

INTERMITTENT WHEAT CULTURE.

While the Hessian fly is a winged insect and capable of traveling to some distance, the fact appears to be that it prefers to deposit its eggs in the immediate vicinity of the place of its emergence. This is considered especially true of the adults from the spring brood, which are supposed to select the tillers in the field where they emerge rather than to scatter to adjacent fields. The interruption of wheat culture, therefore, for one or two seasons, even if adopted on a single farm, will have an appreciable effect in preventing injury to the crop in after years. A suitable rotation, even as applied to a single field, is counted as serviceable in the reduction of Hessian fly injury. If communities can adopt a uniform system of rotation or alternation of wheat crops with crops that are not capable of supporting the Hessian fly they should secure almost perfect immunity from this pest. In fact, this seems to me to be practicably accomplished throughout a large part of the State of Iowa, where wheat is grown as an occasional crop and the Hessian fly has been practically unknown since the early settlement of the State.

PASTURING WITH SHEEP.

One of the methods suggested in the early history of the Hessian fly problem was that of pasturing the winter wheat for the purpose of destroying the larvæ. The first published account of the insect states that by feeding the crop very close in winter and spring, if the land is rich it will again spring up and the worms do not much injure the second growth. If practiced at the right time it is possible that the eggs might be nipped off and devoured with the leaves, but if it is remembered that the eggs usually hatch within four days after deposition, that the plants at this time would furnish rather limited pasturage, and that the larvæ soon after hatching make their way down to the

surface of the ground or below it, it will be seen that there is little basis for favorable results in this method. If the flies are noted as depositing freely at a particular time, and sheep or other stock are turned in at once in sufficient numbers to graze the crop pretty closely, a considerable reduction of larvæ might result. The method, however, involves pretty close observation on the part of the farmer to determine the fact of deposition.

ROLLING.

The suggestion that the passing of a heavy roller over the ground will serve to crush the eggs has been commented on by Fitch. He suggests that it may be successful, particularly on fields that are so smooth and free from stones that almost every plant will receive a firm pressure by the operation. Necessarily the method must be applied immediately after deposition of eggs, and Fitch suggests that some plan of brushing the leaves would be still more effective by dislodging the eggs and preventing the larvæ from following their usual course into the sheath of the young plant.

MOWING.

Of this method Fitch says:

Mr. Goodhue, of Lancaster, Wis., in a communication in the fifth volume of the Prairie Farmer, suggests that the larvæ concealed within the base of the leaves may be destroyed by mowing the wheat and feeding it to the stock. We deem this proposal a valuable one for exterminating the second or spring brood from a wheat field. In those cases where the worms are discovered in the month of May to be fearfully numerous at the joints of the young stalks, there can be little doubt but that on smooth ground the scythe may be so used as to take off almost every spear below where the larvæ lodged; and that thus a second growth of stalks will be produced, quite free from these depredators. The following facts lead me to believe that on a fertile soil wheat may be thus mowed with little if any eventual injury to the crop. Portions of a field of my own, the past season, grew so rank that, deeming that it would become lodged and mildewed, by way of experiment a space in it was mowed down after the plants were two feet in height, and another after the heads had begun to put forth. Though not so early in ripening, the appearance of these two patches at harvest proved, so far as a single experiment could do, that wheat might be mowed at the former period without any diminution of its productiveness, while at the latter both the straw and heads would be of a more slender and feeble growth.

There would seem to be few occasions where this method could be used, and I am confident that in the majority of the Western States it would be entirely impracticable, as the presence of the fly is not manifest early enough in the season to permit of its adoption.

SELECTION OF RESISTANT VARIETIES OF WHEAT.

From early times there has been a recognition of the fact that certain varieties of wheat were much less subject to injury than others. Considerable literature has accumulated concerning these "fly-proof" varieties. The varieties possessing these qualities are such as have coarse and siliceous stems, enabling them to stand and not break over

from the presence of the fly. Varieties which tend to develop secondary shoots or "tillers" are also considered preferable during seasons when the Hessian fly is prevalent. Of such varieties a considerable list has accumulated, many of which are doubtless obsolete at the present time. The Underhill variety is stated to have been the favorite for nearly a century. The Mediterranean wheat has been held in high repute in the Middle States, as also the Red Cap and Red May. The Clawson receives strong commendation from various sources, and Professor Cook speaks of it as a favorite variety in Michigan. The Spelter, China, and White Flint are mentioned by Fitch, but do not seem to have remained in favor.

Prof. C. W. Woodworth improved the opportunity of the occurrence of the Hessian fly in the experimental plats of the University of California to note the effects upon different varieties, and made a list including something like a hundred and twenty different varieties.

He tabulates his result for the three years 1886, 1887, and 1889, and summarizes his conclusions as follows:

Volo and Washington Glass are the only varieties that have remained free from the Hessian fly. The latter, however, never yields well with us. Several other varieties have a very good record. Especially free from the fly are the following: Bearded Wheat from Missoyen, Forelle, Palestine, Polish, Blue Grass, Common March, Diamond, Egyptian Imported.

The following varieties have had more or less fly, but never in abundance: Bearded Macaroni, Big Long-bearded Club, Egyptian, Genoese Winter, Greek Atlanti, Hunter's White, Imported Circassian, Nicaragua, Nonette Lausanne, Red Club, Russian Red Bearded, White Club.

He further makes a comparison of early and late varieties, and of 100 early varieties only 45 were badly infested, against 67 of the late, an advantage for the early varieties of over 20 per cent.

This question seems not to have received as much attention in Europe as in America, but Miss Ormerod has named the Square Head, the White-chaff Red, Golden Drop, and Rivett's Red as resistant varieties, while in France Marchal cites M. de Biguet, professor of agriculture, as recommending the Bordeau wheat as a resistant variety.

USE OF INSECTICIDES.

There seems to be scarcely any reason to expect success from the use of direct remedies in the form of insecticides, but some efforts have been made in this direction, and attempts to destroy the larvæ with lime, soot, salt, etc., have been made. None of these, however, seems to us to have sufficient merit to deserve extended notice. Aside from the expense and labor of their employment, there is little reason to believe that they will accomplish as much as the more simple methods of farm practice. The same may be said with still greater emphasis concerning all suggestions as to treatment of the seed wheat, since there is no possible connection between the seed wheat and the infestation of the field.

COMBINATION OF REMEDIAL MEASURES.

A little thought concerning the measures which have been discussed above, with a recognition of the life-history facts upon which they are based, will suggest that the best practical results will be obtained not by reliance upon any one method, but by an intelligent adaptation of two or more, according to the conditions prevailing for the season. These will constitute a practice which can be modified for each year as the conditions will indicate.

With the harvesting of the grain, there is open the policy of burning the stubble or plowing it under or allowing it to stand for the exclusion of parasites. If the weather is very dry, it will be best to defer burning, to allow the issuance of as many parasites as possible, but if burning is to be adopted at all, it should be done before fall rains set in or the field has grown up to weeds. If rains occur early, burning will be best; and in any case the stubble should be plowed under and rolled as soon as there is any appearance of a volunteer growth of wheat. The chaff from threshing should be burned and the screenings burned or fed to stock as early as possible, and care should be taken during autumn to plow under and roll the volunteer wheat that springs up in the stackyard. If winter wheat is to be planted, strips of decoy wheat may be put in to be plowed under at the end of three or four weeks, and finally the crop planted at as late a date as practicable, according to dates given in the paragraph on late planting. This practice can be duly combined with the selection of resisting varieties of wheat and the application of fertilizers.

It will be observed that the modifications are based primarily on the weather—whether dry or moist, a condition apparent to everyone, and that the suggestion amounts to postponement of burning or plowing if dry, or the early adoption of one or both if wet.

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EXPLANATION OF PLATES.

PLATE I.

A wheat plant showing an uninjured stalk at left and one infested wit
at right, the latter dwarfed, leaves withered, and stem swollen at thre
the ground, where the "flaxseeds" are located, between the leaf-sheat
a. Egg of Hessian fly, ♀ greatly enlarged, as are all figures except *e* an
b. The larva—enlarged, the line by the side showing natural length.
c. The puparium, "flaxseed," or pupa case.
d. The pupa or chrysalis.
e. Adult female, natural size, ovipositing.
f. Adult female—much enlarged.
g. Male—much enlarged.
h. "Flaxseed" in position between leaf-sheath and stalk.
i. Parasite *Merisus destructor*, male—enlarged.

From Packard, Third Report U. S. Entomological Commission; *b*, d
Riley; *d* and *f* by Mr. Burgess; *a*, *g*, *e*, *i* by Packard.

PLATE II.

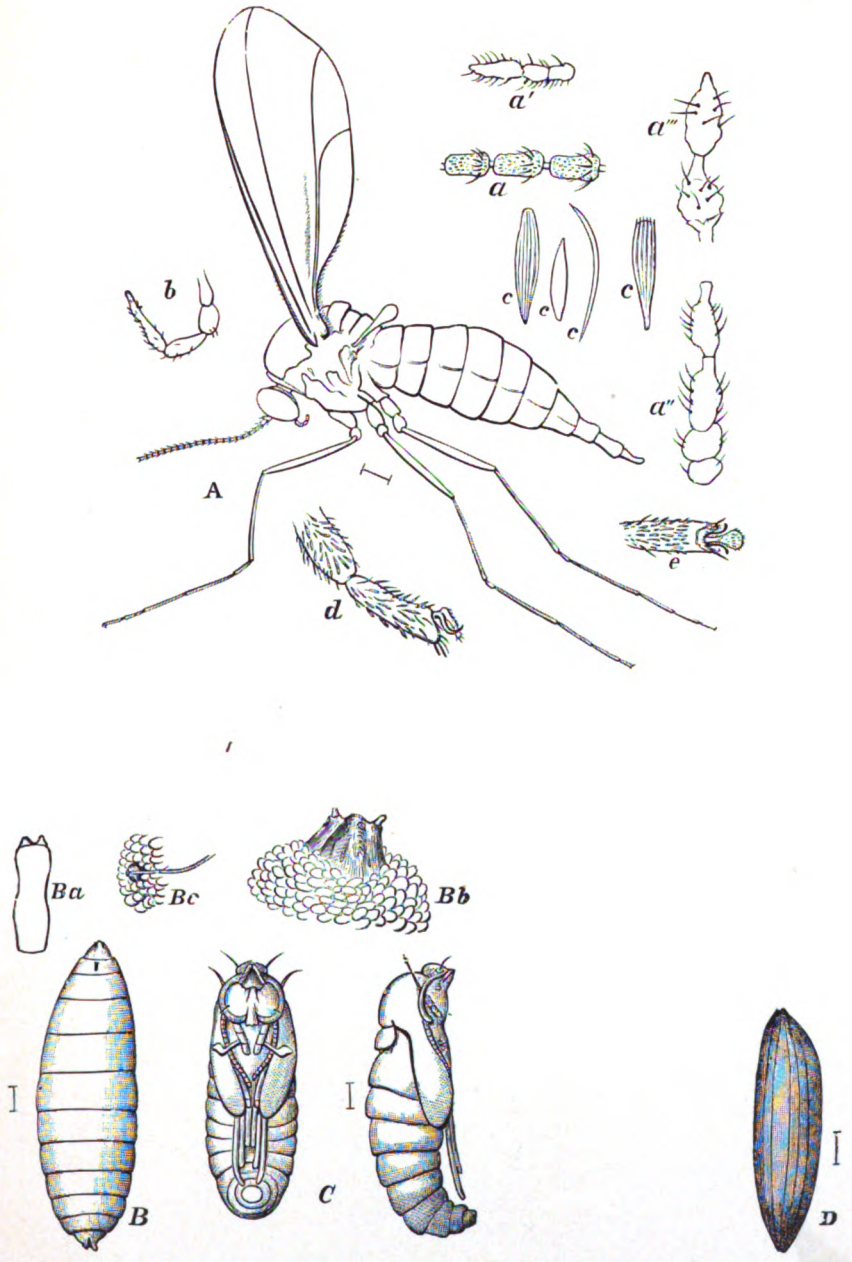
Fig. A. Side view of the female—greatly enlarged: *a*, three joints ta
middle of antenna of female; *a'*, the three terminal antenn
the four basal; and *a''*, the two terminal male antennal join
illary palpus; *c*, scales from body and wings; *d*, *e*, side and
of the last joint of the foot, showing the claws and footpad
between them, and the scales on the joint. Drawn by E. Bu

B. Larva magnified, with the breastbone in the second next ring
B*a*, the breastbone highly magnified; B*b*, head from benea
B*c*, larval spiracle and its tubercle and trachea leading from
B drawn by Dr. Riley; B*a*, B*b*, B*c* by Mr. Burgess.

C. Side and front view of the pupa or chrysalis. Drawn by E
abdomen of the side view is rather long, as the insect whe
just emerging from the semipupal stage, which it assumed I

D. The "flaxseed," puparium or pupal case. The line by the sid
plete figures denotes the natural length of the insect. Pla
Packard, Third Report U. S. Entomological Commission.

WHEAT PLANT SHOWING INJURIES BY HESSIAN FLY; ALSO STAGES IN DEVELOPMENT OF THE INSECT.



DIFFERENT VIEWS OF HESSIAN FLY AT DIFFERENT STAGES; ALSO PARTS ENLARGED.